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An Astronomical Pilgrimage

The noun in the above title carries the connotation of a long and weary journey. It does not, however, necessarily imply that the journey is purposeless and unrewarding. In fact, the best known pilgrimages on record were undertaken with great enthusiasm or even with religious fervor, and brought untold satisfaction and great exaltation of spirit to those engaged in them.

An astronomical pilgrimage, therefore, should possess these characteristics, and, indeed, it does. To be sure, modern means of locomotion have removed much of weariness from travel, but it still requires effort and perseverance to reach the great outposts of astronomical activity. For very definite reasons they are situated in relatively remote places and at relatively high elevations. Whatever mechanical assistance one may invoke, he reaches his destination with a distinct feeling of accomplishment.

Then comes the reward. To observe the starry sky unobstructed by buildings and artificial illumination; to step inside the majestic dome which shelters the delicate and responsive instrument; to note the darkness and the quiet which pervade the surroundings; to have a word with the scientists who are in charge; perchance to see the faint image of a star, formed by the huge telescope, which tells such a fascinating story to those who can comprehend it; these experiences create a profound and lasting impression.

In case the pilgrimage extends into foreign lands, the impressions are the same, for the astronomical phenomena remain unchanged; the same moon, the same sun, the same diurnal succession of day and night, the same planets, the same configurations of stars. In a word, an astronomer on a pilgrimage is never far from home.

One comes down from the mountain chastened and inspired; chastened, because of the immensity of the universe with which his recent experience has put him in rapport; inspired, because it is his mind, and the mind of mankind, by which he is able to come to this recognition of the universe and of his place in it. C.H.G.

A Model of a Nova Outburst

By DEAN B. McLAUGHLIN

Introduction

In earlier articles of this series[1,2,3,4,5,6] the observed phenomena of novae have been described in some detail and a few of the more obvious interpretations and derived facts have been pointed out. But we cannot be content to stop with the mere recording of phenomena and facts. To state it directly, the question before us now is: what *is* a nova outburst; what do the complicated changes of luminosity and spectrum *mean?* The human mind, scientific or unscientific, is always reasoning to conclusions that are not entirely obvious and that are beyond the range of direct observation; in short, it is human to theorize. The more facts we know, the more narrowly is the permissible range of our speculations limited. Our present knowledge of novae is far from being so complete that we can point to a definite model and claim that "this is it." But one has only to examine the literature of a few decades ago and to note the serious proposals that involved pressure broadening of lines, anomalous dispersion, and multiple stars, to recognize how greatly the field has been narrowed down. Permissible models of a nova are now limited to variations upon a single theme: the explosive ejection of the outer layers of a star.

General Considerations

Two results have emerged very clearly from the observational material:

(1) A nebulous shell of gas[6] actually travels outward around the star with fairly uniform velocity and eventually fades away, while still expanding with about the same velocity. The backward extrapolation of the expansion indicates a radius close to zero* at the date of light maximum of the nova.

(2) When the nebular shell has faded away, the remaining star is a hot subdwarf,[7] with a radius of the order of $0.10\odot$ and surface temperature about 50,000° K.

In addition, the observed equality of pre- and post-nova luminosities of the star,[8] the fact of variability in some cases both before and after the nova episode, and the existence of repeating novae, all strongly suggest the conclusion:[2,3]

(3) The structure of the pre-nova star differs slightly, if at all, from that of the post-nova object; the ejection of the shell has decreased the mass by a trivial amount.

Between the pre-nova state and the well-delevoped nebular stage there is a period during which complicated and violent changes of lum-

*This means a radius extremely small as compared with the visible nebula, that is, a radius of stellar order of magnitude.

inosity and spectrum take place. It is with the detailed interpretation of these changes that we are now concerned.

Any hypothesis of the structure of the gas layers about a nova must account for the following sequence of stages that we observe in the spectrum.[5]

(a) Before and at maximum there is an absorption spectrum with a strong displacement towards shorter wave-lengths. Only rarely are conspicuous bright lines present during this stage.

(b) During the rise to maximum luminosity the spectral class of the absorption spectrum becomes later and the lines strengthen in a manner that suggests the transition from low to high luminosity.

(c) Just after maximum, rather suddenly bright bands emerge. Their centers are in the normal location and the dark lines, still with a strong violet shift, lie upon their shortward edges.

(d) Immediately after maximum the pre-maximum absorption spectrum is replaced by the principal absorption with a somewhat greater shift towards the violet.

(e) As the light of the star declines, certain selected absorption lines disappear, while others remain strong.

(f) Another absorption spectrum, the "diffuse enhanced" system, appears with an even greater negative shift, at the hydrogen lines and at a few enhanced metallic lines. These lines, first wide, strong, and diffuse, later split into multiple sharp absorption components before they fade away.

(g) An "Orion" absorption spectrum with high negative displacement appears later, with broad hazy emissions. In its later stage, strong NIII absorption lines may show pronounced oscillations of position, accompanied by "flaring" of the emission at λ 4640.

(h) Following this the spectrum develops into the nebular stage. The emissions of this stage are clearly developed from the principal emission that appeared after maximum light.

(i) The expansion and fading of the nebula leave the post-nova star, a hot subdwarf, commonly with bright lines of hydrogen, HeII, and CIII, somewhat similar to a Wolf-Rayet star, though with much narrower lines than the typical members of that class.

One of the most important clues of all is indicated under the item (h) above. The study of positions of maxima and minima of intensity in the emission band structures shows definitely that the same body of gas that gave the early post-maximum emission is responsible for the nebular emission, and in the later stages of the nova this cloud of gas is visible as a true expanding nebula about the star.[9,10] These facts completely dispose of earlier interpretations of the broad bands in terms of pressure broadening, anomalous dispersion, or rotation. We may take it as demonstrated beyond any reasonable doubt that the broad emissions at all stages of the nova represent true *Doppler* broadening, and that this is due to the line-of-sight components of velocities that are

radially outward from the star. Other interpretations were perhaps admissible when we had fewer facts about novae. They are not tenable today.

The luminosities of novae at maximum,[4] and their surface temperatures[11] as inferred from either the continuous spectrum or the pattern of absorption lines, require that the effective photosphere of the star at that time have a radius of 100 ⊙ as a lower limit, and 200 to 300 ⊙ for the most brilliant novae. The velocities of expansion are so great that no star of ordinary mass and with such a great radius could annul more than a small fraction of the velocity by its gravitational attraction. Within a few days after maximum light the gas must have travelled so far from the star that any further gravitational effect would be practically negligible.

Modern concepts of stellar constitution and of the physical processes of radiation and absorption of energy lead us to the idea that the photosphere is, to put it loosely, simply the depth to which we see into the vast globe of gas that is the star. The so-called "surface" of the sun is like the surface of a fog-bank. It appears definite enough from a distance, but a nearby view would reveal it as a hazy region of transition from gas that is transparent (except for its absorption lines) into gas that is quite opaque to all radiation. Since we have concluded that the nova ejects gas, we must recognize that, if the ejection is copious enough, there will be an effective photospheric level (at what we call optical depth about 1.0) in the outward-rushing cloud.[12] From this effective level will come a continuous spectrum that we can not distinguish from that of a normal stable star. The thinner layers of gas above this level and between it and the observer will produce absorption lines superimposed on the continuum. Finally, if the more tenuous outer layers are sufficiently extensive and if they emit strongly enough, the parts of these layers not between us and the star should give appreciable emission.

In assigning various spectral features to their places of origin we shall be guided by three main considerations: (1) superposition of absorption on emission and vice versa; (2) character and extent of response to light variations of the star; (3) effects of excitation or of shielding from excitation. Specific details of these observed effects have been presented elsewhere[13] and will not be repeated here.

We shall now apply the foregoing concepts to the interpretation of the spectra of typical novae. It is to be understood that the individual differences between novae will require some modification of details in order to make the model applicable to any specific star. Further, although it is admitted that at several points there is a possibility of interpretations somewhat different from those given, we shall not complicate the description by discussing them. The adopted interpretation is that which, in the author's opinion, is most closely in accord with the facts. While it is believed that in its broader outlines the model is essentially

correct, it must be emphasized that the structures and processes described here constitute a *working hypothesis,* and not a rigorously established body of fact.

The Rise to Maximum

The hot subdwarf star in its pre-nova state has been apparently stable for many years, or varying through a small range. Quite suddenly, and for a reason still unknown, a large amount of energy is liberated below its surface. From the main body of the star a superficial layer is violently ejected into the surrounding space. It is not necessarily a uniform spherical shell, but in the early stages its optical thickness is so great that it can be considered approximately uniform. As it expands, it behaves like an expanding photosphere, and in a sense it may be said that the star is expanding. However, there is no ground for supposing that the entire main body of the star expands. Rather, its surface layers leave it, the next lower layers that remain with the star may be somewhat distended, but the core of the star undergoes no appreciable change. The total mass of material ejected is of the order of one ten-thousandth of the star.[14] The intense ejection is not instantaneous, but takes place during an appreciable fraction of the rise to maximum.

Figure 1 shows schematically five stages of the expansion, from the pre-nova star to the time of light maximum. In sections 2 and 3 of that figure, the copious ejection of matter continues, and the effective photosphere expands. But the density of any given layer of gas diminishes as it expands, and its transparency increases accordingly. Thus, a layer of gas that was deep within the opaque layers during the early stages of expansion finds itself in the surrounding atmosphere at a later stage. The growth of the photosphere is not as rapid as the outward motion of the gas,[15] since the photosphere is simply an optical level in the cloud. In Figure 1, section 2, a chosen atom, A, is just leaving the star and is deep below the "photosphere." In section 3 it is in the deepest photospheric layer, and in section 4 it is well above the photosphere, in the reversing layer where the absorption spectrum is produced. The atom B, ejected later (section 3), has only arrived at the sub-photospheric layer in section 4, but in section 5 it has emerged into the reversing layer. However, the radius of the photosphere has steadily increased up to the date of light maximum. The luminosity of the star has increased because the effective area has grown. This occurs in spite of an appreciable drop of photospheric temperature. If we had the complete record of the expansion all the way from minimum, it is probable that we should find a continuous drop of photospheric temperature from about 50,000° K in the pre-nova star to 8,000° or so at light maximum. The supply of energy from within the star raises the luminosity enormously, but it is unable to maintain the surface temperature against the cooling effect of the great expansion.

Figure 1 should make it clear why we observe an intensification of the absorption spectrum as maximum is approached, quite apart from

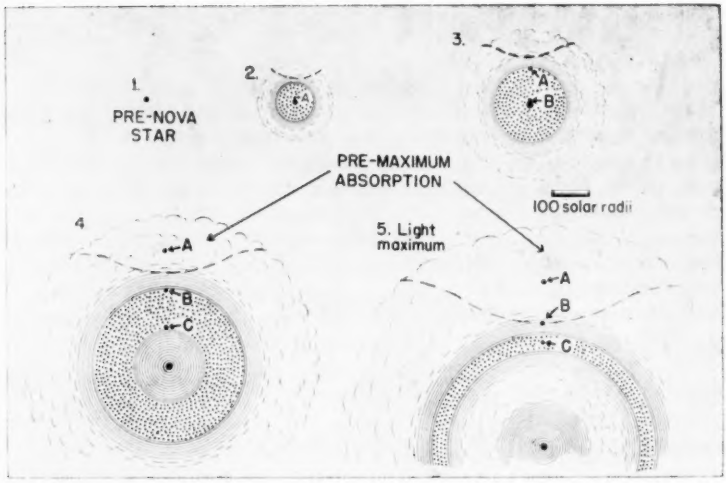

FIGURE 1

Cross-sections of an active nova during the increase to maximum. The observer is above the top of the figure. The large black dot is the main body of the star. Stippled area represents the densest part of the ejected material, in which opacity is great. Concentric circles represent the optically thinner photospheric layers, which merge into the cloudy forms that represent true atmosphere, highly transparent except in its line frequencies. In each diagram, a heavy dashed line outlines the region that is effective in producing the observed absorption spectrum. Successively ejected atoms, A, B, and C, are shown. Note that with expansion the layer containing A, and later that containing B, become transparent. By light maximum, C has begun to overtake B. The atmosphere is now of great depth, and the pre-maximum spectrum is correspondingly strong. At this time the ejection has abruptly diminished and the shell, still opaque and acting as an expanding photosphere, has become detached, though ejection from the star is continuing

the change of spectral class that accompanies the decrease of temperature. More atoms lie above each unit area of photosphere at light maximum than at any earlier time. The spectrum appears like that of a supergiant star because, at the moment in question, the expanded photosphere and its overlying extensive rarefied reversing layer are equivalent to a supergiant.

In section 4 a rather abrupt decrease of ejection is indicated by the use of the symbol for lower density near the star. The thick shell has become detached, not in the sense that a complete vacuum exists inside it, but that the gas within is less dense than the shell itself. As expansion continues the thickness of the photospheric layers becomes less and less, through the emergence of the outer strata of the dense shell into the reversing layer. Evidently it will not be long before the continuous opacity of the main shell will clear away completely and the photosphere as such will cease to exist in the ejected shell.

Section 5 shows another noteworthy point. Atom C is overtaking atom B. The mechanism is somewhat as follows. Radiation pressure from within the shell is able to act directly only upon the innermost layer of the shell, whose opacity screens the overlying strata. But by collision of the inner layer with the next outer one and of that one in turn with the next, the whole shell may be accelerated.[16] The inner layers thus tend to engulf the outer ones and to sweep them on outward at higher speed. But at light maximum this has not yet begun to affect the velocity of the observable reversing layer in which the pre-maximum absorption spectrum is produced.

The Early Post-Maximum Stages

The maximum of light is the critical stage at which the diminishing optical thickness of the expanding shell passes the value 1.0. From then on the shell is fairly transparent to observable radiation, except for its line frequencies, and the continuous spectrum comes from a much smaller effective photosphere in an expanding cloud around the central star. For the moment we ignore this inner cloud, save for our recognition that in the following stages it is the source of most of the continuous spectrum.

The most obvious effect of the sudden transparency of the shell is the emergence of the broad bright bands. Until light maximum the opacity of the shell had prevented our seeing its far side or indeed any part of its inner layers. Now we suddenly see entirely through it. The strong emission from its far side, and from its inner layers where they are moving across the line of sight, or even approaching us, produces the effect of the Doppler-widened bands. The old Halm model of a thin shell attributed the emission and absorption to the *same layers*. Emission was produced by all of the shell except that part between the observer and the star, which gave the absorption line.[17] This model is too simple, and when its details are worked out it fails to account for the existence of *black* absorption lines.[18] We have to recognize that in all stages the principal shell is of great depth. In the early post-maximum stages it is quite transparent in the observable region of the spectrum, *but is highly opaque to radiation of wave-lengths shorter than the limit of the Lyman series of hydrogen.*[19] The emission is produced mainly by recombination of atoms and free electrons that were separated by absorption of high-frequency (ultra-Lyman) radiation from the star. Since the shell is opaque to that radiation, the ionization can occur only at its inner surface. Accordingly the emission that results from recombination originates only on the inner surface of the shell.[20] The absorption, on the other hand, originates throughout the depth of the shell, and the outermost atoms, if they are not shifted off frequency by Doppler effect, can absorb emission that comes from the inner ones. Hence the absorption lines cut off the shortward edges of the emission.[21] This is plainly seen in the comparison of velocities of the edges of permitted and forbidden emissions. The longward edges agree, but

the shortward edges of permitted emissions are clearly cut off by overlapping absorption, while the forbidden emissions, having no corresponding dark lines of appreciable strength, give a higher velocity of approach.

Figure 2, section 6, shows a cross-section of the nova just after maximum. The ejected shell is transparent, and both atoms C and B have overtaken A; that is, the innermost layers have swept up a great deal of the intermediate material. The resulting shell is called the principal shell and the absorption spectrum it gives is called the principal spectrum. During the process of sweeping up, the lowest layers might show a high velocity while the outermost were still undisturbed and still thick enough to produce strong absorption lines. Thus it happens

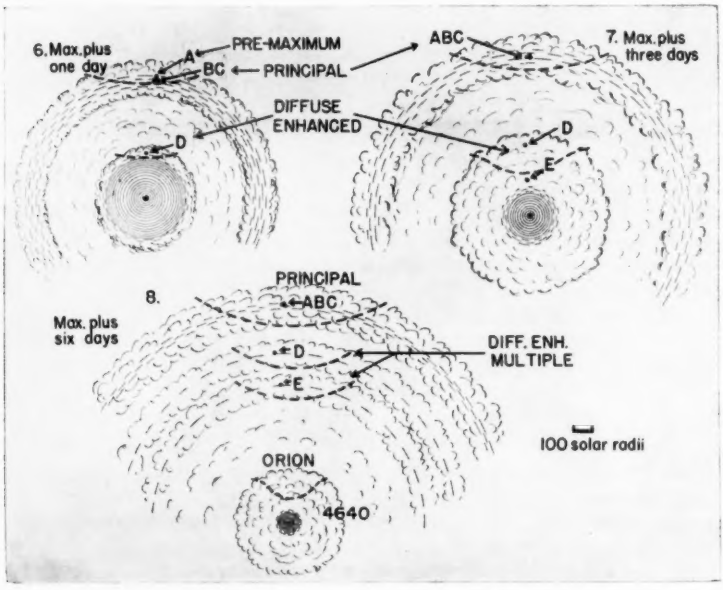

FIGURE 2

Cross-sections of an active nova during the early decline. Symbols have the same meaning as in Figure 1. In section 6, the shell has just become transparent. Atoms B and C, owing to increased velocity of the inner parts of the shell, have overtaken A, and the resultant shell is the "principal" shell, the pre-maximum spectrum having disappeared with the engulfment of the outer layers (A) in the accelerated inner ones (B and C). Atom D, in the atmosphere about the inner ejected cloud, is contributing to the "diffuse enhanced" absorption. In section 7, the inner cloud has become more extensive and the diffuse enhanced spectrum is correspondingly stronger. Atom E is emerging into the absorption region. In section 8, the gas ejected in the diffuse enhanced stage is in the form of two detached shells, overtaking the principal shell, while the inner cloud has developed into the Orion and "4640" spectral stage.

that for a short time the two spectra, pre-maximum and principal, may exist together, but inevitably the rapidly moving inner layer sweeps up the outer. The pre-maximum spectrum then disappears in most novae. In some, however, it has persisted feebly for a number of days after maximum. This may mean that, by the time the rapidly moving gas reached the outermost layers, both were of such low density that the one was able to pass through the other without engulfing quite all of its atoms.

Now let us turn our attention to the region close around the star. Material is still being ejected in large amount, though far less in quantity than during the main outburst. In the cloud about the star there is an effective photospheric level, and outside of this a region where absorption lines are produced. The absorption spectrum that originates here is the "diffuse enhanced" system, whose velocity is much greater than that of the principal shell. This system is at first feeble because the amount of gas above the photosphere is small. As this inner atmosphere increases in depth, we get not only stronger absorption lines but also emission from those parts of the atmosphere that are not directly in line with the observer. The gases have high turbulence or a wide spread of velocities, and the lines are correspondingly diffuse. The stage of full development of this inner P Cygni-like cloud is shown in Figure 2, section 7.

The rate of ejection continues to decrease steadily and the "photosphere" therefore shrinks into the outward-moving gas. The expanding layers that are shed from the star uncover a smaller but hotter effective photosphere beneath. The parts of the reversing layer immediately above this hotter photosphere respond to the higher excitation and an Orion absorption spectrum emerges. Gases farther out, which earlier produced the diffuse enhanced spectrum, remain shielded from the high excitation by the underlying layers, but the remnants of the fading diffuse enhanced spectrum at this later stage are produced in detached shells of gas. These have become organized into shells with discrete velocities through the action of radiation pressure. Thus, the innermost part of a given layer will be directly accelerated by the strong Lyman α emission from the cloud about the star. Collision of this inner stratum with the one above will accelerate the upper one. However, if the original spread of velocities is great enough, an outer layer may lie outside the profile of the absorption line Lyman α for the inner layer. In this case, it will be able to absorb radiation to which the inner is transparent, and the outer layer may thus be accelerated independently. The great Doppler width of Lyman α in the inner emitting region will assure the existence of plenty of radiation of the necessary frequency to supply the outward momentum. Two or more separate sharp components of the diffuse enhanced absorption may be produced by the process just described.

Figure 2, section 8, portrays this stage of the nova. The inner cloud

produced Orion absorption and emission, including the hazy "4640" band and the accompanying wide diffuse emission of NIII about Hδ. The discrete shells that develop from the diffuse enhanced cloud give multiple absorption components just before they overtake the principal shell. In a somewhat later stage these components disappear, either because too little gas lies between the observer and the photosphere, or because the shells in which they are produced become incorporated in the principal shell. By this time even the principal absorption spectrum has been reduced to narrow sharp lines. Even if the original principal spectrum was very diffuse, the later stages of it are quite sharp. The only satisfactory explanation that has been proposed so far is that of radiation pressure plus collision, which brings the entire shell or a large part of it to the same velocity. Weaker satellite lines sometimes occur; these are probably due to independent acceleration of an outer thin shell, as just explained.

The manner of fading of the principal absorption spectrum is most interesting. Such lines as SiII 4128, 4131, MgII 4481, and several lines of OI weaken quickly, while those of hydrogen, FeII, and especially TiII, remain strong. The explanation[22] is to be found in the extreme dilution of the radiation that excites the principal shell when it is far from the star. Atoms that have metastable states will tend to accumulate in those states. The lower energy levels of the conspicuous lines of FeII and TiII are metastable; therefore at any time there will be many atoms ready to absorb such quanta as do pass their way. On the other hand, the lower levels of the lines of SiII, MgII, and OI have strong transitions to still lower levels, and no accumulation of atoms in those states can occur. With the continued expansion of the principal shell and the reduction of size of the effective photosphere, the number of absorbing atoms is eventually so reduced that no trace remains of the principal absorption spectrum. The last lines to disappear are those of hydrogen, and in some novae one or two lines of HeI whose lower states are metastable.[23] The shell, however, is still intercepting high frequency radiation and its atoms are being excited or ionized. Emission bands with the typical broadened pattern of the principal set therefore remain the most outstanding features of the spectrum.

The Transition

Between 3.5 and 6 magnitude below maximum the light variation may change its character, and the spectrum undergoes a change from "stellar" to "nebular" type. This interval we call the "transition" stage.[24] The light variation may take one of three forms: (1) a sudden decline through several magnitudes, followed by a great recovery, as in Nova Herculis; (2) a series of semi-regular oscillations of brightness (Nova Persei 1901); (3) a steepening of the decline, followed by a levelling off or a slight increase (Nova Cygni 1920).[25]

During the period that just precedes the disappearance of the princi-

pal spectrum, the Orion absorption fades and most of its lines disappear. The strong lines of N III near Hδ remain longest, except for two very hazy absorptions attributed to N V which have been seen in a few novae. The broad diffuse N III emissions at Hδ and at λ 4640 are the most conspicuous features of the Orion emission spectrum. They are produced in the violently expanding cloud very close about the star. As they fade away, corresponding narrower bright bands appear in the principal spectrum. That they were not present earlier is attributed to lack of such high excitation in the principal shell. While the inner cloud was giving a strong 4640 band, all the radiation capable of exciting that line was being used up in the inner cloud. Only after the opacity had cleared away (with the slackening of the ejection from the star) was the star able to shine through to the principal shell and produce such high excitation in it.

At about the same time the forbidden "nebular" lines of [O III] appear in the principal shell. As these strengthen relatively while the metallic lines disappear, the spectrum develops into one that resembles in composition that of a planetary nebula. The shell of gas is indeed, temporarily, a planetary nebula, for the density is low, the temperature of the star is high enough to ionize the gases, the dilution of radiation is comparable with that in a planetary, and the free electrons released from hydrogen are numerous enough to excite by collision the atoms of O III, N II, Ne III to metastable states, whence they drop to lower energy states with emission of the forbidden lines.

In some novae strong oscillations of brightness have occurred during the transition from the stellar to the nebular stage. These can hardly be interpreted otherwise than as actual secondary outbursts of the star. In each case the spectrum changed conspicuously during these oscillations, and the excitation was much higher at the minima of light than at the maxima.[26] When the nova brightened, the 4640 and 4100 bands flared and the N III absorption lines appeared at the shortward edge of 4100. With the flaring of these bands, which arise in the cloud close to the star, the bands of the same origin in the principal spectrum disappear. Evidently all the exciting radiation is again used up in the inner cloud, leaving none for the principal shell. With the fading of the star the flared bands fade and the high excitation emissions reappear in the principal spectrum. The nebular lines of [O III] are commonly weakened (though perhaps only *relatively* to hydrogen) when the flarings occur.

In Nova Persei during the minima of these oscillations a comparatively narrow bright line appeared at λ 4686.[27] There is no reason to doubt that it was due to ionized helium ejected from the central star with low velocity, only 200 to 300 km/sec. On a few plates *near but not at minimum,* undisplaced He II *absorption* was probably present. This was certainly the case, very conspicuously, in the spectrum of Nova Geminorum 1912.[28] A similar effect was noted at the secondary

brightening of T Coronae Borealis.[29] Now the *low* velocity of ejection shown by the narrow emission feature is approximately the velocity of escape from a star of very ordinary mass if the distance of the gas from its center is only a few times the radius of the sun. At the minima of the oscillations the calculated radius of the nova is just of that order of magnitude. The absorption feature therefore may represent ionized helium whose outward motion has been stopped by the gravitational attraction of the star.

In the post-nova stage the spectrum of the star often has narrow bright lines of hydrogen and HeII.[30] The minima of light during the transition are times when the ejected cloud close around the star clears away sufficiently to permit us a partial glimpse of the star with its glowing atmosphere of ionized helium slowly expanding from it. But after such a glimpse a new eruption increases the apparent photospheric radius and obscures our view of the star.

Structures of Emission Bands

When the bright bands of the principal spectrum emerge just after maximum they ordinarily appear pretty uniform. Later they develop very pronounced maxima and minima of strength. It has already been suggested that the first emission is produced simply at the inner surface of the shell. In that case no structure could be observed, since differences of concentration of gas would have little effect. As the gas thins out, however, the exciting radiation penetrates farther into it and maxima and minima due to knots of denser gas can be expected to show up. These maxima and minima first appear faintly only a few days after maximum light, but they require several days more to develop to their full strength. A most important characteristic of the structural pattern is that, once it is established, changes are slight.[9,10,31] The same maxima and minima can be recognized many months later; in Nova Aquilae 1918 they lasted fully four years, and in Nova Persei 1901 the expanding nebula after a third of a century showed a distribution of brightness that accorded well with that of the early post-maximum bands. From this it appears very probable that most of the material of the shell is ejected within a short interval of time, possibly no more than a few hours.

In some novae, shortly before the transition stage, the band structures have smoothed out. Then in the fully developed nebular stage they have reappeared in full force *with the same pattern*. The erasure of the structures is not fully explained to my satisfaction, but it appears certain that it is an excitation effect and not a destruction of the shell. I believe it is due largely to the screening of the stellar radiation from the principal shell by the copious ejection of gas that produces the diffuse enhanced and Orion spectra. Much of this gas must overtake the principal shell and be added to its inner layers, and only after further expansion would the excitation again penetrate throughout the

shell. By that time the spectrum has entered the nebular stage and no further weakening of structure in the bands has been recorded.

The Final Decline

The nebular stage of novae has been discussed already at considerable length[6] and we therefore give it only brief notice. During this stage, from six or seven magnitudes below maximum until the end of the decline, the observed light comes from two widely separated sources: the central star and the expanding principal shell. The star has a continuous spectrum and comparatively narrow bright bands (or wide lines) and this spectrum persists long after the nebula has faded away. The end of the transition does not find the star in the post-nova state. It is probably still over-large and hotter than normal, possibly 100,000° K. Certainly its luminosity continues to decrease during the time the nebular shell is disappearing. The shell emission weakens faster and the star finally remains as the only observable source of radiation. When last seen the shell is still expanding with the same velocity, and there is no reason to expect it to be appreciably retarded by the interstellar medium while it is still dense enough to be observable. The star simmers down, and some fragmentary evidence[32] indicates that the last magnitude of its decline may be due chiefly to a cooling of its surface to the pre-nova temperature of about 50,000° K.

No nova has been followed long enough and continuously enough after its decline to determine whether the narrow bright lines are eventually lost. Some objects observed soon after the cessation of light variations have merely a continuous spectrum; others long afterward still have bright lines.[30] But the luminosity in each case differs rather little, if at all, from that of the pre-nova star, and a long period of quiescence or of slight variation follows. Occasional abrupt minor outbursts may occur, as in Nova Persei 1901[33] which brightened by two magnitudes in 1948. Several novae with ranges of less than nine magnitudes have repeated after a number of years. But in all novae of great range, a full-scale repetition of the outburst is not to be expected for thousands of years.

Origin of the Outburst

The preceding account has outlined the inferences that have been drawn concerning what happens in the observable layers of a nova. But nothing has been said as to *why* the outburst occurs, because we are still ignorant of the cause. Even if the above hypothesis of structure should prove to be correct in every detail (which is too much to hope for) we would still be far from understanding the basic cause of novae. It is my belief that the approach to that aspect of the problem must be mainly theoretical. Just as we can never penetrate observationally into the interior of a normal star, so we can never hope to obtain direct evidence of the cause of the outburst of a nova. But some of our observations may be the means of deciding on the truth or falsity of suggested causes.

The energy released in a nova outburst is of the order of 10^{44} to 10^{45} ergs.[34] This is roughly the kinetic energy of a star of solar mass moving with a velocity of 10 km/sec. A stellar collision, however, owing to the gravitational attraction of the stars, would occur at a relative speed higher than this by a factor of the order of 100 and would release 10^{48} to 10^{49} ergs, approximately the amount in a supernova explosion. On this ground alone we can rule out head-on stellar collisions as a cause of common novae. And the frequency of occurrence of novae is much too high to be compatible even with grazing collision or tidal encounter.

Collision of a star with a dark nebula enjoyed some popularity in the past and probably satisfies the requirement of agreement with the observed frequency of some 20 novae per galaxy per year (if we take the Andromeda spiral as typical). Still another hypothesis was proposed by W. H. Pickering[35] many years ago: a nova might be caused by the collision of a "planetoid" with a star. If bodies of asteroidal dimensions were sufficiently numerous in space, the frequency of novae could thus be accounted for. But if such bodies are abundant, it is curious that no hyperbolic asteroids have ever been discovered.

Our current knowledge of the characteristics of novae almost completely rules out all hypotheses that involve an external catastrophic or "accidental" origin of novae. It seems clear that potential novae are a special class of stars and that the outburst is a peculiar property of that class alone, and not a mere accident that could happen to any star chosen at random. The phenomena of recurrence, especially in the allied U Geminorum stars, are clearly opposed to an accidental cause. The frequency of recurrence seems to require that the cause be superficial rather than deep-seated.

We seem to be limited to the conclusion that the cause of the outburst lies in the outer layers of a dense subdwarf star. Biermann[36] showed that, on certain assumptions, such a star would have beneath its photosphere an unstable layer in which a change-over from radiative to convective equilibrium might set off the explosion. He estimated that possibly one percent of the total mass of the star would be involved in the release of energy (but not in the ejected material). The source of energy would be the recombination of electrons with stripped or partially stripped atoms. The hypothesis encounters difficulties, for the unstable layer could exist only in a star in which the abundances of both hydogen and helium were low, and the spectra of novae do not suggest a distinct scarcity of those elements.

Evidently we are still very far from a satisfactory hypothesis of the origin of novae. Nevertheless, the feature of Biermann's hypothesis that involves the release of energy by recombination appears attractive as an explanation of the continuous process of ejection. In the pre-nova star, the subphotospheric layers are subject to enormous gas pressure and radiation pressure from within, but are held down by the weight

and the back-pressure of the overlying photospheric strata. So long as the latter remain undisturbed, the former will stay in their place. But if some agency (as yet unknown) raises the surface layers enough to relieve the downward pressure appreciably, an outward motion will begin. The under layers will expand, relieving the pressure on those still deeper down. The resulting adiabatic cooling will permit recombination of ions and electrons, and each recombination will release a high-energy quantum of radiation. The radiation pressure from the hot region beneath each temporarily superficial layer will accelerate atoms to high velocity, and the continuous ejection of "diffuse enhanced" and "Orion" atmospheres will go on until the cooling due to expansion has descended into the star deeply enough to establish a quasi-equilibrium. The new surface layers after the "transition" stage may be at a temperature of 100,000° K, which is considerably above the temperature of the surface before the outburst. But before the outburst, these new surface layers were deeper within the star and had a temperature considerably higher than 100,000° K.

If the preceding speculation is approximately correct, then our search for the cause of novae must be a search for the lid-lifting agency, the force that raises the surface layers and permits the star's internal energy to do the rest. A potential nova is analogous to a geyser just before eruption, or to a gun loaded and at the ready. We do not need to identify a source of 10^{45} ergs, for the star already contains many times that quantity. What we do need to identify is the finger that pulls the trigger.

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The Observatory, University of Michigan, October, 1949.

Early Days at Mount Wilson

By WALTER S. ADAMS

In keeping with our plan, stated on page 301 of Volume 57 (1949), of publishing a series of papers under the general title of "Papers on Historical Astronomy," we are constantly on the lookout for material for it. The paper by Dr. Walter S. Adams entitled "Early Days at Mount Wilson," which appeared in Publications of the Astronomical Society of the Pacific, *Vol. 59, Nos. 350, 351 (October, December, 1947) seemed to us to be eminently suited to our purpose. Our request for permission to reprint this paper in* Popular Astronomy *was readily granted by the author and by the editor, Dr. Seth B. Nicholson. Dr. Nicholson, in a footnote states that these reminiscences were written for the staff of the Mount Wilson Observatory. We believe that the names of those persons, who contributed to the establishing and developing of this well-known Observatory, are so deeply written in the astronomical literature as to be familiar to many of our readers. We, therefore, are pleased to have the opportunity of printing this paper by Dr. Adams in this and the succeeding issue.* Editor.

The history of the origin and development of the Mount Wilson Observatory is primarily the story of the insight, enthusiasm, and courage of a single individual. Those who were fortunate enough to be associated with George Hale at the Yerkes Observatory, and to come with him to California when the Mount Wilson project began to develop, had long recognized these qualities as well as the rare personal charm and highly cultured intelligence which made him such a delightful companion on every occasion. But even they were hardly prepared for his reaction to the novel and primitive conditions which were encountered during the early years on Mount Wilson. Apparently combined with a deep-seated love of nature in every form was the spirit of the pioneer, whose greatest joy is the adventure of starting with little and taking an active personal part in every phase of creation and growth. To both of these inborn characteristics of Hale, Mount Wilson in 1904 offered a rich field and full scope for their employment.

THE CASINO
First living quarters on Mount Wilson (1904)

It is difficult for anyone in later years to realize how simple were conditions in southern California when the first steps were taken in the establishment of the Mount Wilson Observatory. Pasadena was a town of about fifteen thousand inhabitants spread widely over a large area. Open country with vineyards and orange groves intersected by rambling dirt roads occupied what is now the closely built area along North Lake Avenue, while eastward of this street were only occasional farmhouses and small dwellings set in a semidesert environment. Small private water companies furnished a more or less intermittent service to their subscribers, and water shortages followed almost invariably upon winters of deficient rainfall. A prominent and rather amusing feature of what might be called the business district of Pasadena, then essentially limited to Colorado Street between Fair Oaks and Marengo Avenue, was the elevated wooden structure beginning at Colorado Street and extending southward as far as the Raymond Hill. This was a portion of a proposed cycleway by means of which residents of Pasadena could, for a moderate toll charge, ride their bicycles into Los Angeles over a wooden runway free from the difficulties of roads deep in sand and the inconveniences of horse-drawn traffic. The enterprising company which conceived this project was so unfortunate as to start operations just at the beginning of the motorcar age, but may be said to have anticipated to some degree the modern Parkway.

As might be expected, access to Mount Wilson and conditions on the mountain top were equally simple and verged upon the primitive. Two trails led to the summit; the first, the old Indian trail leading from Sierra Madre up the canyon of the Little Santa Anita stream; and the second, the trail built by the Pasadena and Mount Wilson Toll Road Company, beginning at the mouth of Eaton's Canyon in Altadena and zigzagging up the rugged southern face of the mountain range. The ambitious name of "toll road" was given to this trail, averaging about two feet in width, but it was not until it was widened by the Observatory in 1907 to provide for the transportation of the 60-inch telescope that it became in any sense an actual road. The two trails were for many years familiarly known as the "old" and the "new" trails, respectively.

On the summit of the mountain the only building was the so-called "casino," a log cabin, built of cedar logs in 1893 and abandoned after a few years. At the time of Hale's first visit to the mountain in 1903 the roof had partially fallen in, and he often spoke of the first night he spent within the building lying on a cot and watching the stars crossing a hole in the roof some twenty feet in length. The heavy log walls, however, were in good condition, and it was clear that simple repairs would make the cabin at least temporarily habitable for a small group. Two mountain camps were not far away: Martin's Camp, which was open throughout the year, on the saddle of the ridge joining Mount Wilson and Mount Harvard, and Strain's Camp on the north side of the mountain near the springs producing the main water supply. Both

camps were small, especially Martin's Camp, and consisted of a few cottages supplemented by tents. Strain's Camp, which was open only during the summer months, had an attractive location in a grove of large incense cedar trees. It was a favorite vacation resort during the warmer months of the year. The camp was named after a pioneer who lived on Mount Wilson for several years, developed the water supply, built the casino, and originally owned much of the land around the mountain top.

Transportation in the mountains at this time was, of course, wholly by pack train, and the general term of "animal" was applied to the miscellaneous and picturesque assortment of burros, mules, and occasional horses which were maintained in a stable or corral at the foot of the old trail in Sierra Madre for carrying visitors and supplies to the various mountain camps. "Ordering an animal" was the regular expression for engaging a beast of burden in case the visitor did not wish to face the rigors of the eight-mile climb to the summit of Mount Wilson wholly on foot. But as experience often showed, the passenger on a mule or burro fully earned his passage. Books could be written about the personal characteristics of these sagacious beasts and the infinite variety in their individual behavior. One would deliberately expand his chest when the saddle was placed upon him so that the rider, after a good start, would presently find the saddle rolling beneath him at some awkward point in the trail; another would groan heavily when the grade became steep, but if the rider once dismounted, he would be fortunate to overtake his mule within several miles; while still a third would show an almost irresistible desire to roll over, frequently selecting a stream bed for this purpose.

The names of these animals had in most cases been bestowed upon them by the pack-train drivers, a somewhat philosophical group of individuals skillful in throwing a diamond hitch, extremely resourceful, but owing to their profession endowed with a lurid vocabulary and a distinctly pessimistic outlook upon life. They had to be prepared for the worst in dealing with their charges and usually encountered it. Nevertheless, the drivers were proud of their animals, learned their characteristics and various abilities, and took excellent care of them in times of trouble. Each problem of transportation was solved separately, one mule being selected for his riding qualities, a second for his strength, and a third for his ability to carry a top pack or to swing widely at the turns of the trail. An astonishing feat of skillful planning was the successful transport of a 225-pound metal bathtub to the halfway house on the old trail. For several years one particular mule made a regular practice of carrying up this trail a resident of the Mount Wilson Hotel whose average weight was 268 pounds. The burros that carried lighter loads handled most of the material dealt with in quantity, such as cement, lime, lumber, and structural steel. The limits set by such methods of transportation necessarily affected every feature of the

design of the earlier buildings of the Observatory, and it is of interest to realize that no single structural member of the Snow telescope building exceeds eight feet in length. Similarly, the wooden doors of the original Monastery, which was burned in December, 1909, were limited to a width which would permit of their transportation on the sides of a burro without dragging on the ground. As it was, several of these doors when installed were found to be slightly rounded at the corners where they had touched the ground occasionally during the long journey up the trail.

Two anecdotes of these early years will serve to illustrate the variety of emergencies encountered in days when the departure of a pack train was in the nature of an adventure, and the journey might be compared to a voyage with the destination sometimes in doubt. On an August morning in 1904 a pack train of mules and burros set out over the new trail loaded with unslaked lime intended for use in the construction of the large stone pier at the south end of the Snow telescope building. Summer rains are almost unknown in southern California, but on this occasion nature contrived to time a heavy shower with the presence of an exceptionally vulnerable cargo on the open trail. When the storm broke, the pack-train driver had no choice but to cut the packs loose to save his animals from severe burns, and the lime rolled into the canyon where it remains to this day.

The winter of 1906-7 was notable for one of the heaviest snowstorms in the history of the Observatory, the snow reaching a depth of over sixty inches on the top of the mountain and extending far downward on the slopes and into the canyons. A few days after the storm a pack train was organized to carry needed supplies to the Mount Wilson Hotel and the Observatory, and was placed in charge of an experienced but highly profane driver. All went well until the pack train reached the portion of the trail on Mount Harvard above the deep canyon west of the Monastery. Here, where the snow had completely obliterated the trail, one of the mules stepped off and rolled over and over, down the mountain side, to the bed of the canyon. The deep snow prevented injury to the mule, but there was no possible way of getting him out until the snow had melted considerably. So for some weeks the positions of the mule and the driver were reversed, the driver packing hay on his back to feed the mule, who apparently enjoyed his vacation. The language of the driver in describing the situation was notable even among the remarks of his highly competent fellows.

By far the most picturesque animal in the early history of the Observatory was a burro, Pinto by name. His age and origin were wrapped in obscurity, but when we first knew him he was mature, to say the least, had a long, melancholy face, and walked with a slowness which distinguished him even among his slow-moving comrades. An interesting feature was a tail of only half the normal length, the remainder of which, according to a tradition carefully fostered by Pinto's

owner, had been bitten off by a mountain lion one winter when Pinto was out at pasture in the vicinity of Barley Flats. Pinto, the property of Mr. Bassett, proprietor of Martin's Camp, was purchased by the Observatory for the sum of five dollars to pack water from the springs at Strain's Camp to the Monastery in the days before the pumping system had been installed. An Armenian was in charge of Pinto on these expeditions and together they formed one of the familiar and pleasant sights of these early days. Like most burros, Pinto had a catholic taste in food, and in the absence of anything better would devour newspapers, magazines, or any other debris along the trail, sometimes even licking up the earth along the banks. A discovery which endeared him particularly to Professor Barnard was that Pinto's hair, being considerably finer than human hair, was exceptionally well suited for making cross-wires in a guiding telescope, a purpose for which it was used during Barnard's stay at Mount Wilson. With the completion of the pumping system the need for Pinto no longer existed and he was sold back to Mr. Bassett. The fate of Pinto is uncertain, but for several years he served as an attraction for children at Martin's Camp, often being photographed with several on his back. We may hope that he died peacefully in the fullness of years and of wisdom as befitted one of his philosophic type.

It is hardly possible to estimate how much these faithful and interesting animals contributed to the Observatory at a time when everything depended upon transportation, and the arrival of the pack train was the chief event of each day and determined the course and progress of construction. Considerable risks were involved, and, as was said of the pioneers and adventurers of old, their bones are scattered far and wide along the trails leading up the mountain sides. The burro Brigham Young lies buried halfway up the Sierra Madre where he fell over a precipice, and Jasper, the mule, at the head of the canyon between the Observatory and the Hotel where he was hauling stone for the pier of the Snow telescope. Like Duck and Jerry and Agnes and Maude, they played an important role in a vanished phase of the early life of the Observatory and the neighboring mountain camps.

The story of the foundation of the Observatory is so well known that it requires little comment here. It passed through three phases which followed closely upon one another. At first it was simply an exploratory expedition to investigate observing conditions on Mount Wilson, and was financed personally by Hale and a few individual gifts. At this time a small coelostat was erected near the casino on the present hotel site, and photographic observations of the sun were carried on directly as well as spectroscopically with a long instrument placed in a temporary tube north of the coelostat. They were supplemented by visual observations with a portable four-inch refracting telescope equipped with a polarizing eyepiece. The results were so satisfactory that an application was made by Hale to the Carnegie Institution for a grant

to bring the Snow telescope of the Yerkes Observatory to Mount Wilson on an expeditionary basis. The grant, amounting to $10,000, was made in April, 1904, and most of the summer of that year was devoted to laying the foundations, constructing the piers, and designing the building for this instrument. Before its completion, however, the confidence which President Woodward and the Trustees of the Institution placed in Hale and his plans, together with a change from their previous policy of making a large number of small grants to investigators throughout the country to one of establishing major departments within the Institution itself, resulted in the appropriation of a large amount for the establishment of an independent observatory. The third and final step had been taken, and the Solar Observatory, as it was known during the years preceding the completion and operation of the 60-inch telescope, began its interesting career. The hopes of its courageous founder had been richly fulfilled.

The members of the staff of the Yerkes Observatory who came to Mount Wilson with the Snow telescope and remained to take part in the establishment of the new observatory were Ritchey, Ellerman, and Adams. Francis Pease came about one year later. Ritchey had been instructor at a Chicago manual-training school, and was primarily a draftsman and designer. At the Yerkes Observatory he developed much skill in optical work and also became an able observer, especially with the 24-inch reflector in the design and operation of which he took a leading part. At Mount Wilson he designed much of the earlier equipment, more especially the 60-inch telescope and dome which have now been in active operation for more than forty years with comparatively little modification. He also carried through successfully the figuring of the 60-inch and 100-inch mirrors together with their auxiliaries. Ritchey's main observing interest lay in direct photography, and his absorption in this field was so intense that it handicapped to some extent the design of instruments which had to be used for many different purposes. As an observer he was most painstaking, and the admirable photographs which he obtained in the early years of the 60-inch telescope have proved of great value in later investigations. In personal relations Ritchey was somewhat difficult, and it is a tribute to Hale's unfailing tact and consideration that their association lasted throughout so many years.

Ellerman was of quite a different type. His long association with Hale at the Kenwood and Yerkes Observatories, his observing and photographic ability and experience, together with his ingenuity and mechanical skill, made him invaluable, especially during the years of construction and development on Mount Wilson. If anything went wrong with an instrument he could almost invariably repair it or at least make it operate temporarily. This ability was of immense value at a time when transportation was slow and difficult, and the fifteen miles separating the Observatory from its instrument shop in Pasadena

formed a gap which it took the better part of a day to cross. So during these early years we depended upon Ellerman in a thousand ways, and it was a rare occasion when he could not meet the emergency.

As was the case with the other members of the small Yerkes group, the somewhat wild and primitive conditions on Mount Wilson were quite new to Ellerman and he enjoyed them greatly. He had seen but few mountains previously, and the views with their outlook upon the valley and the deep canyons, the new trees and flowers, and occasional glimpses of wild animals all made a strong appeal to his love of nature. He would have ranked high on John Buchan's criterion that "there is something wrong with the man who sees a high mountain and does not want to climb it," for Ellerman was an ardent mountain climber. The occasional rattlesnake and the almost mythical mountain lion provided the element of excitement, and he made elaborate preparations for meeting them. On my first trip up Mount Wilson, Ellerman and I met at the foot of the new trail. He wore a "ten-gallon hat," high mountain boots, and a full cartridge belt from which hung a revolver on one side and a hunting knife on the other. Naturally I was greatly impressed and pictured a struggle for existence on the wild mountain top, which bore little resemblance to later actuality. Together we explored many trails and climbed the higher mountains to the eastward. Ellerman was a most pleasant companion on all such expeditions, and recollections of these walks and of occasional games of golf in the valley form some of the pleasantest memories of these early years on the mountain.

Pease was an able designer and optician and developed greatly as his responsibilities grew. His patience knew no limit, a quality which stood him in good stead during the earlier years of his association with the Observatory. He became a remarkably skillful observer, devoting to his work exceptional care and thought and all the resources of his technical knowledge. His affection for the Observatory was profound, and he spared neither time nor strength in its service. As a comrade and friend he was unfailingly cheerful at all times, and his sudden death in later years brought to everyone a feeling of personal loss and full realization of his notable contributions to the success of the Observatory.

The heart and center of the small group was George Hale, then in the prime of life and full of enthusiasm over the almost boundless prospects opened out by the generous action of the Carnegie Institution. In the establishment of the Observatory he found the complete fulfillment of his ideal of an institution devoted purely to research, free from many of the restrictions imposed by university affiliations, and able to build its equipment to fit the problems he had in mind instead of seeking the problems to fit existing or preconceived instruments. In addition, the mountain in all its varying aspects was a source of perpetual delight to him. Its quiet and peace, the sense of remoteness and isolation, the changing views, and the brilliant skies by day and night were a constant joy. He often called himself a sun-worshiper, and nothing pleased him

Pier of Snow Telescope (1904)

Small Truck for Hauling Material on Mountain Trails (1904)

PACK TRAIN ON MOUNT WILSON (1904)

more than to leave Pasadena on a summer morning when the valley was covered by fog, and halfway up the trail to burst out into the bright sunshine and see the distant mountain peaks outlined against the deep blue sky. He enjoyed, too, all the simple activities of these early days, the exploration of the mountain, examination of the water supply, the selection of sites for buildings, and the erection and testing of the instruments, most of them temporary in character, which were used for much of the earlier work. From his boyhood he had loved to work with machine tools and had developed very considerable skill in the use of the lathe and milling machine. This skill he put to active use on the mountain, and many a temporary slit or lens or grating mounting of this period was built by Hale with his own hands.

The winter of 1903-4 was spent by Hale and his family in Pasadena. He then returned to the Yerkes Observatory for a brief stay and, on coming back early in March, brought Ellerman with him to begin systematic observations on Mount Wilson with the small coelostat. Late in April, Hale went again to the Yerkes Obervatory and this time on his return to Pasadena brought with him Ritchey and Adams. The grant from the Carnegie Institution for the temporary transfer of the Snow telescope to Mount Wilson had just been made and the first steps in the establishment of the new observatory may be said to date from that time. The railway journey from Chicago to Pasadena required four nights and three days, with forty-minute stops at suitable intervals at dining stations along the way. Hale's interest and excitement increased as we neared the end of the journey, for he realized that the decision had been made, and that a new life with new responsibilities and opportunities lay before us all. I remember that the three of us climbed out of our berths at dawn as the train was going through the Cajon Pass, in order to enjoy the abrupt and always spectacular transition from sheer desert to the gardens and orange groves of the coastal plain of southern California.

The plan of organization at the outset was for Ritchey to be in charge of a small machine shop in Pasadena to build auxiliary instruments for the Snow telescope, for Ellerman and Adams to continue the solar observations in Mount Wilson and to assist in the design and erection of the building to house the telescope, and for Hale to divide his time between Pasadena and the mountain. The Carnegie Institution had under consideration at this time Hale's proposal for the establishment of a large independent observatory to include the 60-inch reflecting telescope, and his negotiations with the Trustees and the President of the Institution necessitated repeated trips to the Atlantic Coast. Such was the attraction of the mountain, however, that these absences were made as brief as possible, and on his return Hale was never so happy as when, like a boy on a vacation, he could pack a knapsack and start on the eight-mile climb over the old trail to the summit.

The instrument shop was originally located in a leased building on

Union Street, a short distance west of Fair Oaks Avenue. A year or so later when it became necessary to expand the shop to provide for the construction of the 60-inch telescope, two lots were donated by the city of Pasadena on a short country road called Santa Barbara Street, and the present shop building was erected. Myron Hunt, then near the beginning of his career, was the architect. Hale and Ritchey had small offices in the front of the building, and a portion of the east side was used as an optical shop in which the 60-inch mirror and its auxiliaries were figured. This remote district of the city was very sparsely settled, with only occasional small farmhouses and barns scattered here and there. The streets were narrow dirt roads, and Lake Avenue was not even oiled until several years after the shop building was erected. The principal landmark in the vicinity was a group of pine trees at the southwest corner of Lake Avenue and Santa Barbara Street, in all probability planted by some rancher about 1890 or perhaps earlier. They disappeared when the streets were widened and oiled.

On Mount Wilson the only existing building was the log cabin called for some unknown reason the "casino." It had been made comfortably habitable by the time Ellerman arrived on the mountain, through patching the holes in the roof, repairing the floors, and dividing a large room into small cubicles with building-paper partitions. The outstanding feature of the casino was the huge fireplace in the living room built of large granite blocks and capable of holding logs two feet in diameter. The fireplace and chimney were the handiwork of George Jones, a stonemason by trade, whom Hale had discovered in Pasadena. It soon appeared that Jones could turn his hand to every type of construction and development required by the Observatory, and as superintendent in later years he was responsible for the widening of the new trail into a serviceable road, the transportation of all materials to the mountain, and the erection of every important building and instrument, including the dome and the mounting of the 100-inch telescope. The debt which the Observatory owes to the genial, resourceful, and efficient George Jones is beyond estimate.

The group living in the casino between May and December, 1904, consisted of Hale, during his frequent visits, Ellerman, Adams, and the cook, Wilbur by name. Wilbur was a picturesque individual who deserves a word of comment. Mrs. Hale secured him through an employment agency in Los Angeles, and he proved to be one of the type of wandering camp cooks so characteristic of the Pacific Coast in the early years of its development. He had cooked from the beach at Nome during the Alaskan gold rush, all the way to Panama, seldom remaining long in any one place. In earlier years he had served as a valet to Frank Norris, the well-known California novelist. He had a remarkable facility for preparing an excellent meal out of a minimum of materials, but like many cooks he was extremely temperamental. This was well illustrated one day when Ellerman and I on returning to the casino heard a loud

disturbance and discovered Wilbur chasing Jones with a butcher knife and crying for his blood. The occasion was as trivial as the reaction was drastic. Wilbur remained on Mount Wilson as long as his roving disposition would permit, and then moved on to other scenes and pastures new.

Life was very pleasant on the mountain during this first summer. A regular series of meteorological records was kept, and observations were made of the solar seeing throughout the day. The small coelostat was used for direct photography of the sun and to provide an image on the slit of a temporary spectrograph, the focal length of which could be varied up to as much as sixty feet. The purpose of these latter observations was to test the effect of seeing within the spectrograph itself, and thus to provide a basis for the design of the permanent instruments to be used with the Snow telescope. Early in the summer the site for this telescope had been selected, and soon operations were begun on leveling the ground, laying the foundations, and building the large south pier. Meanwhile, explorations of the top of the mountain for the location of other instruments were in progress. Although the Institution had not yet acted upon the larger project involving the completion of the 60-inch telescope, the prospects appeared favorable, and the selection of a site for this instrument was considered. For a time the choice lay between its present site and the prominent knoll at the northeast corner of the mountain top. Accessibility and less proximity to steep mountain slopes were the determining factors in the selection of the present site.

It was at this time, too, that Hale and Adams set out one day to explore the ridge extending southward from the site of the Snow telescope. Small hatchets were taken along to cut a path through the bush since no trail existed. After working our way slowly downward for a quarter of a mile, we came out upon a small opening free from brush at the very edge of the ridge. The ground was nearly level, with several large spruce trees and a little grass in the cracks of the exposed ridges. On three sides the slopes fell abruptly into nearly sheer precipices, and the view of the valley, the canyons, and the distant mountains was magnificent and quite unobstructed. Hale's enthusiasm was tremendous. "This is where we must have the Monastery," he said; and six months later on a warm and quiet December evening we moved into the attractive building around which so much of our life was to center for several years to come.

While living at the casino we were almost in the path of the visitors who were hardy enough to undertake the eight-mile trip up the old trail from Sierra Madre. About ten days after our arrival, a district convention of the Order of Elks was held at Strain's Camp, about half a mile distant on the north side of the mountain. The officials who planned this outing had clearly made a mistake. The comfortable physique of the average Elk is not at all adapted to several hours of severe mountain climbing, but since the supply of burros and mules at the foot of the

trail could provide for only a fraction of the group, no choice remained for the others but to attempt the journey on foot. As a result, we at the casino had to operate something in the nature of a first-aid station for exhausted Elks during much of one afternoon and evening. Some were still staggering along on their feet while others lay on the ground vowing they could go no farther even if their lives depended on it. The last arrival had been nine hours upon the trail, a record which probably remains good to this day. With a little food in some cases, and more potent stimulants in a few others, we succeeded in restoring them sufficiently to herd them down to the camp. Here adequate preparations had been made for their entertainment. For two weeks before the opening of the convention kegs of beer, Elk's milk as it was commonly referred to by members of the order, had been coming up the new trail. These kegs were piled in the form of a pyramid on a level spot in the center of the camp, and around them gathered the thirsty Elks engaged in a race against time to eliminate the pyramid during the two or three days of the meeting. They were fully successful, but as a mark of gratitude reserved one keg for presentation to us who had played the part of good samaritans at the casino.

Many stories could be told about our experiences during the summer and autumn which we spent in the old casino, where on a cool evening we gathered around the wood fire in the fireplace engaged in planning the work for the following day. George Jones was usually present, and on one occasion fell over backward in his chair when a lizard leaped out of a crack in a burning log and scuttled across the floor to safety. Evidently his comfortable hibernation had received a rude awakening. The workmen engaged in general construction on the mountain under Jones's supervision lived in tents near by and occasionally visited us at the casino. They were an interesting group as a rule, decidedly individualistic, and often with considerable history behind them. I remember one Englishman who had studied at Cambridge and had the soft, cultured English voice. We never knew his history, but he was probably a ticket-of-leave man because of family reasons. Another workman of powerful physique gloried in the nickname of "Sharkey" because of a fancied resemblance to a well-known prize fighter of the day. They were excellent workmen, with an interest in what they were doing and, in contrast to many of their successors, cared little about their hours of work and were ready to help at any time in an emergency. At a period when emergencies were often the rule rather than the exception, this characteristic was exceedingly welcome.

Wild animals, with the single exception of deer, were more plentiful on Mount Wilson in these early years than at present, partly because relatively few visitors came to the mountain, and party because natural conditions were undisturbed. There was a tradition that even an occasional bear was to be seen in the vicinity, although we never encountered one. Hunting was allowed at all times, a fact which doubtless ac-

counted for the comparative absence of deer, and a simple request was sufficient to obtain a permit to carry a revolver or other firearms. As a result we had a small arsenal at the casino and often practiced target shooting, at which Ellerman became especially proficient. The stump of an old pine not far from the casino should some day prove to be a lead mine. Adventures with rattlesnakes were fairly common, and once we had to rescue the casino cat from a coiled rattlesnake he was starting to investigate.

One of our problems at this time was the telephone line which was a constant source of uncertainty, consisting as it did of a single iron wire stretched along on bushes and occasional trees. Even when it was in normal working condition the operator had to shout so loudly that it sometimes seemed doubtful whether the listener did not hear the voice directly rather than through the instrument. We had many exasperating experiences with it and spent considerable time in trying to obtain a satisfactory ground connection, no easy task in the dry decomposed granite of the mountain top. One day soon after we had moved into the Monastery a snowstorm crippled the telephone line and Hale and I started out to try to locate the trouble. We found a broken wire on an oak tree on the ridge near the site of the present 10-inch telescope, and Hale at once started up the tree in the driving sleet to repair the break. As he worked, his enthusiasm, which neither weather nor numb fingers could affect in the least, broke out in the words of his favorite poet, and I heard, "it was a storm from fairyland . . . ." coming down from the tree above the roar of the wind.

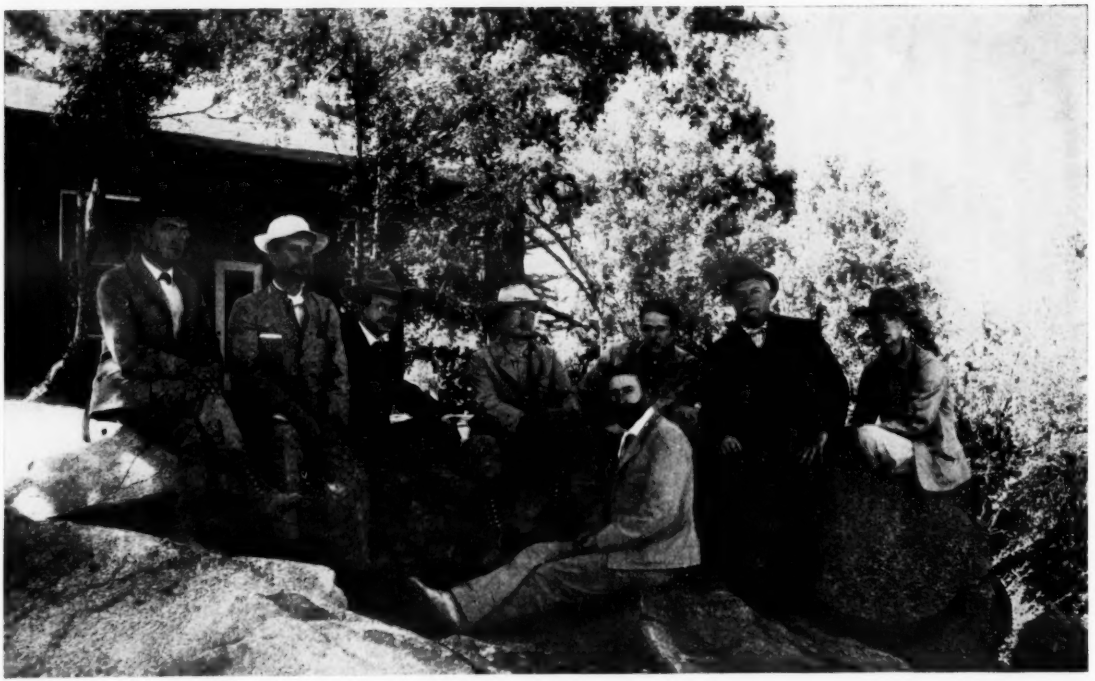
In later years after the permanent telephone line with copper circuits had been installed, the Observatory was fortunate in having a week's visit at the Monastery from General Carty, who was at the time both a trustee of the Institution and a vice-president of the American Telephone and Telegraph Company. General Carty made a practice, in which we encouraged him strongly, of calling his secretary in New York every day to have his correspondence read to him. Needless to say, the unimaginable heights to which the telephone service rose during this period have passed into a tradition which future generations are inclined to call a myth.

The construction of the Snow telescope building and the erection of the instrument were the chief activities of the summer and autumn of 1904. As has been mentioned already, transportation by pack train set a definite limit of eight feet to the length of all structural-steel members in the building. The only exception was the steel bar, ten feet long, to which the windlass for moving the small sliding house over the coelostat was attached, and this required extensive negotiations and the use of a top pack on a selected animal. The transportation of the heavier parts of the telescope mounting, however, presented a difficult problem, since some of them were single pieces weighing as much as 350 pounds and quite beyond the capacity of even the strongest mule. This afforded an

interesting opportunity for the exercise of Hale's ingenuity. He designed a small steel truck about ten feet long, with a width and tread of twenty inches. Small wheels with rubber tires were used and the body was underslung to keep the load close to the ground. The truck was steered from both ends so that it could negotiate the sharp turns in the trail. The motive power was a mule attached to the front end. In operation the truck was a remarkable sight. First came a man leading a mule, next the truck and its load with a man at either end to steer the vehicle, and finally a second mule led in the rear to act as a reserve, or, in case of need, to pull the truck back upon the trail. This unique invention proved most successful and made numerous trips up the new trail, bringing, in addition to the mirrors and mounting of the Snow telescope, the heavy flywheel of the first gas engine to provide electric power on the mountain, and parts of several machine tools. Naturally the truck was slow in operation and a round trip from the foot of the trail required a full day.

Designing the Snow telescope building to insure the best use of the instrument was an important problem, and many experimental tests were made before a final decision was reached. Two related factors were involved. The first had to do with the heat radiation from the ground as affecting the quality of the solar image; the second with the protection of the beam of light inside the house during its long passage from the coelostat to the image-forming concave mirror and back to the focus. It was clear that soon after sunrise the warming of the ground, especially where there was little coverage by trees or brush, would set up convection currents of warm air which were certain to injure the definition of the image. The obvious solution, of course, was to place the telescope and especially the coelostat high above the ground, but considerations of expense and the fact that the Snow telescope was planned to operate in at least an approximately horizontal position set a limit upon the height which could be attained. Some compromise was evidently necessary. So tests were made with the four-inch portable telescope of the quality of the image at various heights above the ground, platforms built on temporary wooden towers being used for the purpose. Hale even climbed a large pine tree near the small reservoir, dragging the observing telescope with a rope to a height of some sixty feet. The ground coverage was also examined and the effect of shielding bare ground in the vicinity of the coelostat with cheesecloth to reduce heating and radiation was tested repeatedly. The final decision was to place the building on the highest point of the selected site, with the coelostat on a stone pier about twenty-five feet in height on the slope below the high point. The height of the coelostat was such that the beam of light to the concave mirror as well as the building itself sloped downward to the north by a very few degrees from the horizontal, and conformed to the contour of the ridge.

The necessity for shielding the beam of sunlight within the building



GROUP AT MONASTERY (1905)

Miller (construction superintendent) Abbot Hale Ingersoll Adams Barnard Backus (assistant)
Ellerman

from injurious convection currents led Hale to adopt the louver type of construction for the walls. The successive skirt-like louvers prevented direct sunlight from reaching the interior of the building but permitted free circulation of air around the closed inner wall. A series of ventilators in the roof allowed the warm air to escape upward.

It is interesting to note how directly Hale's experience with the Snow telescope led him to the design of the vertical tower telescope two or three years later. The tower provided a simple means for obtaining the incident sunlight at a high elevation relatively free from the convection currents near the ground; the lens gave a convergent vertical beam much less susceptible to disturbances than one parallel to the ground; and the vertical spectrograph offered great convenience in use, excellent conditions of temperature control, and the possibility of using much greater focal lengths than are possible for horizontal spectrographs except under the best laboratory conditions.

Since these casual reminiscences are in no sense a history of the scientific work of the Observatory, I am making no attempt to describe in detail the uses to which the Snow telescope was put after completion. Undoubtedly the single most fruitful investigation associated with the instrument was the study of the spectrum of sunspots. To the best of my knowledge the first photograph of a spot spectrum ever obtained was made with this telescope in 1905. A series of excellent spectroheliograms led to the detection of solar vortices, and these in turn to Hale's dramatic discovery with the tower telescope of the magnetic field in sunspots. It is perhaps of interest to note that the first application of high dispersion to stellar spectra was with the Snow telescope. A plane grating, cemented into a metal box filled with water which was maintained at constant temperature, was used with a 13-foot spectrograph on two or three of the brighter stars. Since the grating was not exceptionally bright and the telescope mirrors were usually somewhat tarnished, exposure times were extremely long. A very respectable spectrogram of Arcturus, taken with a total exposure of twenty-four hours on four consecutive nights, is still in existence, however. A comparison with the twenty-minute exposures of Arcturus made with the 100-inch telescope and its coude spectrograph, which gives considerably larger scale and finer definition, affords a slight illustration of the progress of the Observatory since those distant years.

Occasional trips to the valley were interspersed with the work on Mount Wilson. Usually Ellerman and I went separately in order to avoid interruption to the observations, but now and then together, often to play golf on the links of the Raymond Hotel, or, more rarely, on those of the Green Hotel which occupied the area now forming the campus of the California Institute of Technology. For Ellerman, whose family lived in Pasadena, these trips were comparatively simple: he walked the new trail and rode into Pasadena on a bicycle which he kept in a store house at the foot of the trail. For a bachelor, however, the problem was

more complicated and had to be considered in advance because of difficulties of transportation. Until the Pacific Electric streetcar line was extended to Sierra Madre the only method was to walk down the old trail, take an antique horse-drawn bus which operated between Sierra Madre and the Santa Anita railway station, and then board a local train for Pasadena or Los Angeles. These operations, especially if made in the reverse order, often took the better part of a day. Although Ellerman usually walked the new trail beginning at Eaton's Canyon, he frequently used the older one from Sierra Madre. This introduced an element of competition which ended only when both of us had achieved a record of just two hours from the foot of the trail to the laboratory on the mountain. In all we probably made at least two hundred journeys on foot over this trail under all sorts of conditions and in every kind of weather.

(To be continued)

The Planets in March, 1950

By RAYMOND H. WILSON, JR.

NOTE: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac.*

Sun. The sun's northward migration toward summery declinations will be most rapid and noticeable during this month. Its actual crossing of the equator, producing the vernal equinox, occurs on March 20 at 11 P.M. An annular eclipse on March 18 will be visible only from the South Atlantic Ocean.

Moon. The phases of the moon will occur as follows:

Full Moon	March	4	5 A.M.
Last Quarter		10	9 P.M.
New Moon		18	9 A.M.
First Quarter		26	2 P.M.

The moon will be nearest to the earth on March 6.

Evening and Morning Stars. Saturn will be rising at sunset; Mars, shortly later. Venus and, during the latter half of the month, Jupiter will be shining brightly in the eastern dawn.

Mercury. Unfavorable location, culminating with its superior conjunction with the sun on the 27th, will make Mercury practically invisible during this month.

Venus. This brightest planet will be at its greatest brilliancy on March 6, and will thus be the outstanding object in the morning sky after 5 A.M. during the month.

Mars. Since it will stand in opposition to the sun on the 23rd and nearest to the earth on the 27th, the ruddy planet will be around its most favorable aspect for observation.

Jupiter. From an unfavorable position rising only shortly before the sun at

the beginning, Jupiter will become quite conspicuous, just a few degrees east of Venus, toward the end of the month.

Saturn. Opposition to the sun on the 6th will mark most favorable conditions for observation of the ringed planet. However, the rings, being on edge, contribute little light, so the planet will be only slightly brighter than the star Regulus to the west of it.

Uranus. Uranus will be practically stationary at a point about a degree northeast of 1 Geminorum.

Neptune. Neptune will be moving northwestward at about a degree northwest of θ Virginis.

Department of Mathematics, Temple University, Philadelphia, Pa.
January 9, 1950.

Asteroid Notes

By HUGH S. RICE

We offer the following four sets of positions for the brightest minor planets next to come to opposition after those we have given previously. They are all in good locations in the sky for northern observers. The magnitude of each of the first three is 10, and that of Juno is 9.

ASTEROID EPHEMERIDES

0^h U.T. Equinox 1950

187 LAMBERTA

1950	α h m	δ ° ′
Feb. 8	11 6.9	+20 54
18	10 58.6	+21 35
28	10 48.6	+22 3
Mar. 10	10 38.1	+22 13
20	10 28.7	+22 0
30	10 21.4	+21 19

63 AUSONIA

1950	α h m	δ ° ′
Feb. 8	11 27.0	+ 3 36
18	11 19.9	+ 3 49
28	11 10.7	+ 4 18
Mar. 10	11 0.6	+ 4 54
20	10 50.7	+ 5 30
30	10 42.1	+ 5 58

674 RACHELE

1950	α h m	δ ° ′
Feb. 18	12 0.7	+22 26
28	11 53.0	+23 33
Mar. 10	11 43.9	+24 18
20	11 34.5	+24 39
30	11 26.0	+24 36
Apr. 9	11 19.2	+24 7

3 JUNO

1950	α h m	δ ° ′
Feb. 8	12 11.7	— 1 50
18	12 8.3	— 0 44
28	12 2.3	+ 0 39
Mar. 10	11 54.8	+ 2 12
20	11 46.8	+ 3 48
30	11 39.2	+ 5 16
Apr. 9	11 32.7	+ 6 32
19	11 27.9	+ 7 28

Hayden Planetarium, American Museum of Natural History, New York,
1950 January 22.

Occultation Predictions for March, 1950

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from

the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

			IMMERSION				EMERSION			
Date 1950	Star	Mag.	Greenwich C.T.	*a*	*b*	Angle E from N	Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′										
Mar. 1	ω Canc	5.9	1 17.4	−2.0	+0.2	95	2 38.1	−1.6	−1.6	303
1	4 Canc	6.2	2 7.6	−1.4	−2.6	147	3 14.0	−2.3	+0.4	253
5	BD+1°2624	6.4	10 23.2	−0.4	−1.8	135	11 18.8	−0.2	−1.6	287
23	η Taur	3.0	19 35.4	−0.6	+3.8	18	20 36.6	−2.8	−1.3	289
24	BD+24°599	6.4	1 41.2	−0.4	−1.5	94	2 44.4	−0.2	−0.9	251
26	406 B.Taur	5.6	4 54.7	+0.4	−1.6	115	5 46.0	+0.3	−0.9	258
27	54 Auri	5.8	0 58.5	−2.0	+0.1	71	2 5.6	−0.6	−2.8	315
27	25 Gemi	6.5	2 3.7	−1.8	−0.1	64	2 59.5	0.0	−3.0	324
28	*c* Gemi	5.4	5 8.5	0.0	−1.7	118	6 5.9	+0.1	−1.5	282
30	37 Leon	5.7	21 52.5	−0.7	−0.6	144	22 49.8	−1.0	+1.5	265
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′										
Mar. 1	ω Canc	5.9	0 43.8	−1.6	+0.5	104	2 5.2	−1.9	+0.1	281
1	4 Canc	6.2	1 53.9	..	..	182	2 13.1	..	..	207
5	BD+1°2624	6.4	10 19.8	−0.5	−2.1	155	11 14.3	−0.8	−1.5	275
6	319 B.Virg	6.3	10 50.2	..	..	50	11 11.5	..	..	16
10	CD−27°11076	6.5	12 39.5	−1.9	−0.1	69	13 49.4	−1.8	−1.6	309
24	BD+24°599	6.4	1 36.2	−0.7	−2.7	121	2 33.5	−1.2	+0.6	221
26	406 B.Taur	5.6	5 10.2	+0.9	−3.0	151	5 45.6	−0.8	+0.1	224
27	54 Auri	5.8	0 18.3	−2.2	−0.1	94	1 48.0	−1.9	−1.3	283
27	25 Gemi	6.5	1 28.9	−2.0	−0.7	96	2 53.0	−1.4	−1.8	288
28	υ Gemi	4.2	0 7.4	..	..	33	0 36.8	..	..	353
28	*c* Gemi	5.4	5 14.0	+0.2	−2.8	153	6 2.8	−1.0	−0.9	251
Occultations Visible in Longitude +98° 0′, Latitude +31° 0′										
Mar. 1	ω Canc	5.9	0 33.6	−1.8	−1.0	132	1 42.1	−1.8	+2.0	246
5	BD+1°2624	6.4	10 41.4	+0.3	−3.4	186	11 14.9	−1.9	−0.4	249
6	319 B.Virg	6.3	10 37.7	−2.0	−0.8	89	11 35.6	−0.7	−2.5	342
10	CD−27°11076	6.5	12 24.1	−2.4	−0.1	86	13 48.6	−2.2	−1.3	296
23	η Taur	3.0	18 59.3	..	..	346	19 21.4	..	..	314
27	54 Auri	5.8	0 9.1	−2.6	−2.0	128	1 33.0	−2.9	+1.4	243
27	25 Gemi	6.5	1 28.3	−2.0	−2.7	134	2 47.5	−2.8	+0.5	249
27	υ Gemi	4.2	23 26.5	−2.0	+1.5	79	0 50.9	−2.4	−1.3	301
Occultations Visible in Longitude +120° 0′, Latitude +36° 0′										
Mar. 1	ω Canc	5.9	0 12.6	−0.4	+1.2	90	1 18.5	−0.9	+0.8	280
1	4 Canc	6.2	1 8.3	..	..	180	1 15.9	..	..	192
6	319 B.Virg	6.3	9 49.5	−1.6	−1.0	124	11 4.0	−1.3	−1.6	317
10	CD−27°11076	6.5	11 37.4	−1.7	+0.4	105	12 57.8	−1.8	−0.3	294
27	25 Gemi	6.5	0 26.0	−2.3	−0.3	112	1 52.5	−2.3	+1.3	250

METEORS AND METEORITES

Contributions of The Meteoritical Society

(Known Formerly as The Society for Research on Meteorites)

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles 24

The Albuquerque, Bernalillo County, New Mexico, Siderite (ECN = + 1068,350)

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Department of Geology *and* Department of Mathematics & Astronomy,
University of New Mexico, Albuquerque

ABSTRACT

In this paper are given details concerning the acquisition of an iron meteorite (siderite) found approximately 13 miles west-southwest of Albuquerque, in Bernalillo County, New Mexico (equatorial coördinate number (ECN) = + 1068,350). The total mass recovered to date is a single specimen weighing 157.3 gm. Mineralogical, chemical, and radiochemical studies have been made, and, on the basis of these investigations, the meteorite is classified as a medium octahedrite (Om). The original belief that this meteorite might be a stray specimen of the Canyon Diablo, Arizona, fall is refuted by the mineralogical, chemical, and radiochemical findings, especially the last two.

INTRODUCTION

In July, 1943, while Mr. Oscar Branson was stationed at the New Mexico Proving Ground, he had an opportunity to examine a number of iron meteorites now in the collection of the Institute of Meteoritics of the University of New Mexico. In September, 1943, Branson, who is a mineral collector, reported that he had seen a mass of metal in a secondhand store in downtown Albuquerque, and that this metal resembled an iron meteorite. At Branson's suggestion, LaPaz accompanied him to the store, owned by W. Holloway, and was shown an interesting and obviously meteoritic specimen. This specimen was shaped like a 120° sector cut from a nearly circular disk, with a diameter of 12 cm. The disk has a central thickness of about 1.8 cm., but thins out to knife-edge thickness along most of the curved periphery. This sector-shaped piece of meteorite may have been cut out of such a metal disk, because, in addition to the natural, undamaged, curved knife-edge, the wedge is bounded by two plane surfaces, approximately perpendicular to the equatorial plane of the circular disk. These surfaces could be cuts intersecting in the axis of the hypothetical disk. Unfortunately, the meteorite, because it produced spectacular showers of sparks when held against a motor-driven carborundum wheel, had been used as a test object in so many demonstrations of the effectiveness of the wheel that it was impossible to determine whether the plane surfaces had been ground on the wheel or had been saw-cuts partitioning a considerably larger mass. In addition to the damage caused by

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the carborundum wheel, there was a small frothy area on one of the vertical plane-faces that appeared to have been subjected to a hot flame.

According to Mr. Holloway, the meteorite, "in almost its present condition," had been one item in a collection of old tools, scrap metal, and other odds and ends purchased from a Spanish-American family living at a point about 15 miles southwest of Albuquerque. The curiously shaped piece of metal with its two shiny surfaces had caught the junk collector's eye and he had asked where it had been found. The woman of the household replied that she had found the mass in the dry bed of a nearby gulch draining into the Rio Puerco. It was impossible to ascertain the name of the finder of the meteorite, but it has been possible to locate the house in which she probably lived. Several dry gulches exist in the neighborhood of this house, in any one of which, as far as available information goes, the meteorite might have been found. All of these gulches have been hunted over, and the more promising areas near the finder's house have been searched with meteorite detectors. To date, no additional fragments of the meteorite have been discovered.

The solitary mass so far recovered from this fall was found probably at a point about 13 miles west-southwest of Albuquerque. This location has the equatorial coördinate number (ECN) + 1068,350. Because there is no post office any nearer than that of Albuquerque, this iron will be designated as the Albuquerque, Bernalillo County, New Mexico, meteorite. The total weight of the recovered meteorite is 157.3 gm.

Mineralogy

A slice of the meteorite was polished, etched, and studied. The metallographic structure is that of the octahedrites. The bands of kamacite are regular and vary in thickness from 0.6 mm. to 1.1 mm. The specimen may, therefore, be classified as a medium octahedrite (Om). Several sets of well-developed Neumann lines are present in the kamacite bands (Fig. 1).

The taenite bands are very narrow and more or less continuous. Typically,

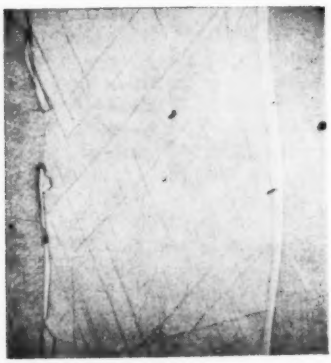


Figure 1
A Kamacite Band Showing Several Sets of Neumann Lines. Narrow Taenite Bounds the Band, × 60: Nital, 15 sec.

the taenite bands bound both sides of the kamacite bands (Fig. 1). The few schreibersite grains found in the polished section concentrate along the mutual boundaries of the kamacite and taenite bands.

Several large fields of plessite have been observed in the polished section—one of these fields reaches dimensions of 4 mm. × 6 mm.—and many small plessite fields are present. Most of the plessite fields consist of granular kamacite with taenite filling in the interspaces (Fig. 2). One area of darkened and dense

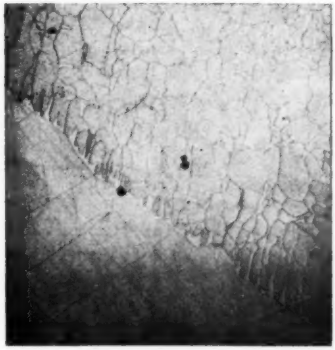


FIGURE 2
A PLESSITE FIELD AND A KAMACITE BAND, × 60: NITAL, 15 SEC.

plessite was noted in the polished section. Under high magnification, this darkened area is seen to consist of tiny particles of taenite and unresolved α-γ aggregate.

Several days after this section had been polished, a brown dendritic growth appeared along some of the boundaries separating bands (Fig. 3). Standard etch

FIGURE 3
A LAWRENCITE DENDRITIC GROWTH ON BOTH SIDES OF A NARROW TAENITE BAND SEPARATING TWO KAMACITE BANDS, × 30:

and microchemical tests show that the dendritic growth is the mineral goethite, FeO(OH). The formation of the brown dendritic growth is due to the presence of lawrencite in the meteorite. After the appearance of the first growth, the section was repolished and examined regularly for several days. The lawrencite manifested itself as tiny, green, liquid drops that oxidized rapidly to the solid, hydrated ferric oxide. The specimen had been polished several times, but always the lawrencite appeared. In an attempt to rid the meteorite of the destructive lawrencite, the polished specimen was evacuated, immersed in warm, distilled water, and then the pressure was restored and the specimen was kept under water for several days. Then the specimen was evacuated again, dried, and repolished; however, the oxidation reappeared. The supply of lawrencite seems endless; this fact, despite the trace of chloride shown in the chemical analysis (*post*).

Analyses

Chemical Analysis of the Albuquerque Siderite.—A second small sample was cut from the meteorite, etched, and examined carefully to make certain that the section for analysis was typical of the meteorite. This sample was then analyzed by Dr. E. L. Martin, Department of Chemistry, University of New Mexico, with the following results:

Fe	90.08%
Ni	8.51
Co	0.90
P	0.40
S	0.00
Cl	trace
Total	99.89%

Molecular ratio: $\frac{\text{Fe}}{\text{Ni}} = 11.12.$ Molecular ratio: $\frac{\text{Fe}}{\text{Ni} + \text{Co}} = 10.06.$

The chemical analysis of this meteorite is in agreement with that of a normal medium octahedrite (Om).

Radiochemical Analysis of the Albuquerque Siderite.—The Albuquerque siderite is one of several iron meteorites made available by the Institute of Meteoritics to Dr. Harrison Brown, Institute for Nuclear Studies, University of Chicago, for radiochemical analysis. Brown analyzed this specimen for gallium, palladium, and gold; the results are given in the first row of Table 1. The corresponding results for Canyon Diablo, Arizona, and Canyon Diablo No. 2, as obtained by Brown,[1] are given in the second and third rows, respectively, of Table 1. The last entry in each row is the percentage of nickel as determined by the Henderson method.[2]

Table 1

	Gallium	*Palladium*	*Gold*	*Nickel*
Albuquerque	90.5 p.p.m.	4.46 p.p.m.	2.67 p.p.m.	8.51%
Canyon Diablo	77.4	3.98	2.10	7.24
Canyon Diablo No. 2	85.0	5.30	1.60	8.09

Summary

Because of its superficial resemblance to certain surface finds at Canyon Diablo, it was thought at first that the Albuquerque meteorite might be a stray specimen of the great Arizona sideritic fall. We are, however, convinced that the Albuquerque meteorite represents a distinct fall. Possibly the most cogent evidence supporting this conclusion is that shown in Table 1. There appear the

differences in the gallium, palladium, and gold content of Albuquerque and of Canyon Diablo. These differences are even more striking than the similar differences, on the basis of which Brown adjudged "that Canyon Diablo No. 2 is a meteorite indeed distinct from Canyon Diablo."[3] In addition to this compelling radiochemical evidence, the presence of lawrencite, the abundant Neumann lines in the kamacite bands, and certain chemical differences support the view that the Albuquerque meteorite is distinct from Canyon Diablo. The chemical analysis is lower in iron and higher in nickel and cobalt than is that of most Canyon Diablo specimens, tho it must be recognized that chemical analyses of Canyon Diablo meteorites are variable.

REFERENCES

[1] Brown, Harrison, & Goldberg, Edward, "The Neutron Pile as a Tool in Quantitative Analysis; The Gallium and Palladium Content of Iron Meteorites," *Science*, **109**, 347-53, 1949; and "A Preliminary Report on the Distribution of Gallium, Palladium, Gold, and Nickel in 45 Iron Meteorites," *C.M.S.*, **4**, 207-8; *P.A.*, **57**, 398-9, 1949.

[2] Henderson, E. P., "Methods of Determining Nickel and Cobalt in Meteoric Iron," *Am. Jour. Sci.*, **239**, 373-8, 1941.

[3] *V.* Brown, Harrison, & Goldberg, Edward, *C.M.S.*, **4**, 208; *P.A.*, **57**, 399, 1949.

On the Nature of the Earth's Core

In *Monthly Notices of the Royal Astronomical Society, Geophysical Supplement*, **5**, 409-26, 1949, a paper with the above title, by W. H. Ramsey of the University of Manchester (England), contains some material of interest to the meteoriticist. The summary and the conclusion of the paper read as follows:

"*Summary:* In a previous paper (*M.N.*, **108**, 406, 1948) the author has suggested that the density jump at the boundary of the Earth's core is due to a phase transition under pressure, and not to the appearance of a new material such as iron. A metallic type of structure was proposed for the material in the core. In the present paper the transition to the metallic phase is explained in greater detail. Seismological data are used to prove that the core cannot be composed of either iron or an alloy of nickel and iron. It is shown how the theory removes certain difficulties arising from the hypothesis of an iron core, and how it can account for features not hitherto explained."

"*Conclusion:* The theory developed in this paper can explain all of the changes in structure in the deep interior of the Earth. It has been shown in a previous paper [*loc. cit., ante*] that it can also account for the mean densities of the terrestrial planets on the basis of identical chemical constitutions. No previous theory has had these merits. Moreover, so far as the author can foresee, no *a priori* objections to this theory can be raised. On the other hand, the objections to the iron-core theory and to the theory of Kuhn and Rittmann [refs. cited] seem to be unanswerable. The present theory of the Earth's interior is the simplest which has been put forward. In it the Earth is of uniform chemical composition, apart from a slight condensation of the heavier elements towards the center. The other terrestrial planets and meteorites have the same chemical composition as the Earth, and this composition is consistent with solar origin. The present theory explains the anomalies just outside the core and inner core in a very natural way;

these anomalies have never before been explained satisfactorily. The sharpness of the core boundary is also support for the theory."

Particular reference should be made likewise to the section of the paper on "The Origin of the Solar System," on p. 424.

President of the Society: ARTHUR S. KING, 925 Topeka Street, Pasadena 6, California

Secretary of the Society: JOHN A. RUSSELL, Department of Astronomy, University of Southern California, Los Angeles 7, California

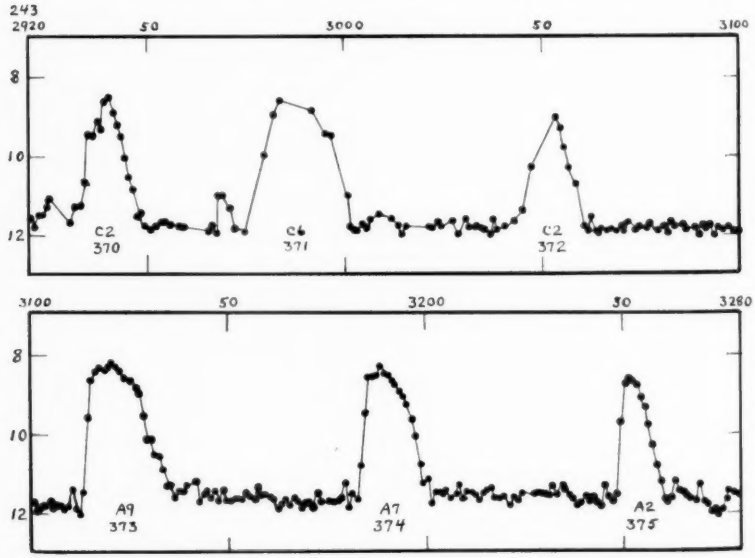
VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By MARGARET W. MAYALL, Recorder

SS Cygni in 1949: This most popular variable star, SS Cygni, 213843, was watched very carefully during 1949. More than 1,000 estimates were made by A.A.V.S.O. observers on 268 nights out of the 330 discussed in this note. There were six maxima observed during the year, the first three of the C-type, and the last three of A-type, according to the classification of SS Cygni light curves given by Mr. Campbell in the *Harvard Annals,* Vol. **90**, No. 3.

The intervals between maxima were somewhat longer than usual, but the star was so well observed, it is quite certain that no maximum could have been



SS CYGNI, DAILY MEANS IN 1949

TABLE 1

DAILY MEANS

213843 SS CYGNI J.D. 2,432,920-3,250

243	—0—	—1—	—2—	—3—	—4—	—5—	—6—	—7—	—8—	—9—
	m_v No.	m_v No.	m_v No.	m_v No.	m_v No.	m_v No.	m_v No.	m_v No.	m_v No.	m_v No.
2920	11.60 2	11.80 2	11.50 2	11.50 5	11.3 1	11.05 2	.....	.....	.....	.....
30	11.7 1	11.3 1	.....	11.3 1	10.65 2	9.5 1	9.53 3	9.12 4	9.35 2	8.63 7
40	8.56 3	8.93 3	9.23 3	9.52 4	10.05 2	10.53 3	10.82 5	11.55 2	11.50 2	11.80 2
50	11.90 4	11.8 1	11.8 1	11.7 1	11.70 2	11.76 3	.....	11.8 1	.....	11.8 1
60	.....	<10.0 1	.....	.....	.....	11.95 2	11.75 2	12.0 1	11.0 1	11.0 1
70	11.35 2	11.9 1	.....	.....	11.95 2	.....	.....	.....	.....	10.0 1
80	.....	.....	9.0 1	8.60 2	.....	.....	.....	.....	.....	.....
90	.....	8.9 1	.....	.....	.....	9.45 2	9.5 1	.....	.....	.....
3000	11.0 1	11.8 1	11.9 1	11.9 1	11.75 2	11.9 1	11.6 1	.....	11.5 1	.....
10	.....	11.6 1	.....	11.8 1	12.0 1	11.80 2	.....	.....	.....	<9.6 1
20	.....	11.8 1	11.8 1	11.70 2	11.8 1	.....	.....	11.65 2	12.0 1	.....
30	11.60 2	11.80 2	11.80 2	.....	11.85 2	11.90 3	12.0 1	11.60 2	11.9 1	11.85 2
40	11.80 2	.....	11.7 1	.....	11.40 2	.....	.....	10.3 1	.....	.....
50	.....	.....	.....	9.05 2	9.3 1	9.8 1	.....	10.30 3	10.7 1	.....
60	11.8 1	11.90 2	11.56 5	11.92 4	11.96 3	11.85 2	11.90 2	11.83 3	11.90 4	11.8 1
70	11.9 1	11.7 1	.....	11.90 2	11.8 1	11.8 1	11.8 1	11.70 2	.....	11.9 1
80	11.8 1	11.96 3	11.70 4	11.8 1	11.75 2	11.76 3	11.85 4	11.83 3	11.80 3	12.00 3
90	11.78 9	11.86 7	11.73 3	12.0 1	11.80 4	11.87 7	11.80 3	11.80 2	11.95 2	11.95 2
3100	11.73 3	11.93 7	11.85 2	11.8 1	11.5 1	11.9 1	11.80 4	11.80 2	11.90 2	11.85 4
10	11.4 1	11.92 4	12.03 3	10.45 6	9.58 5	8.66 3	8.43 7	8.33 9	8.40 3	8.30 8
20	8.22 4	8.31 15	8.40 13	8.60 10	8.58 12	8.63 6	8.85 6	9.00 3	9.57 7	10.17 8
30	10.18 9	10.53 3	10.56 6	10.90 5	11.32 5	11.32 5	11.60 2	11.45 2	11.45 10	11.30 2
40	.....	11.20 2	11.76 5	11.57 8	11.47 7	11.65 4	11.45 2	11.70 2	11.43 10	11.69 10
50	11.71 14	11.64 13	11.60 7	11.62 10	11.48 7	11.53 9	11.66 5	11.36 3	11.53 16	11.54 7
60	11.60 5	11.67 13	11.87 6	11.78 4	11.66 5	11.80 2	11.6 1	11.70 2	11.90 2	11.78 6
70	11.76 7	11.85 4	11.50 2	11.72 6	.....	11.71 7	11.72 4	11.74 9	11.65 6	11.26 5
80	11.88 10	11.50 4	11.65 4	10.80 7	9.47 11	8.54 11	8.52 11	8.50 7	8.28 4	8.46 8
90	8.53 15	8.62 6	8.74 5	8.92 5	9.03 3	9.22 4	9.60 2	10.03 3	10.74 5	11.23 6
3200	11.13 3	11.75 4	11.46 5	11.43 6	11.56 3	11.40 4	11.60 8	11.50 3	11.25 4	11.66 3
10	11.42 8	11.42 4	11.57 7	11.70 5	11.48 5	11.4 1	11.39 7	11.63 6	11.62 4	11.57 7
20	.....	11.8 1	11.6 1	11.66 3	11.5 1	.....	.....	11.55 2	11.5 1	11.50 7
30	11.52 4	11.57 3	11.3 1	11.55 6	11.3 1	11.39 7	11.54 5	11.62 4	11.93 3	11.75 4
40	11.60 2	11.70 7	11.60 8	11.74 10	11.80 2	11.3 1	11.60 2	11.72 5	11.53 3	9.70 2

missed. The mean cycle derived from the maxima of 1949 is 60 days, as compared with the mean value of 51.7 days for the 375 maxima observed since its discovery in 1896.

Table I contains the daily means of the estimates, a continuation of the table given by Mr. Campbell in his Variable Star Notes for March, 1949 (*P. A.*, **57**, 141). The observed maxima are listed in Table II, with the dates at which the

TABLE II

OBSERVED MAXIMA

No. Max.	Type	J.D. 10.0 I	Diff.	J.D. Max.	Diff.	J.D. 10.0 D	Diff.	Max. Mag.
370	C2	2432936	44	2432940	43	2432944	41	8.5
371	C6	2980	44	2988	48	2998	54	8.6
372	C2	3048	68	3053	65	3057	69	9.0
373	A9	3114	66	3120	67	3129	72	8.3
374	A7	3184	70	3190	70	3197	68	8.5
375	A2	3249	65	3252	62	3257	60	8.6

star reached 10.0 magnitude on both the increasing and decreasing branches of the light curve. The figure shows the light curve for the year, from J.D. 2,432,920 to 3,280.

Observations received during December: A total of 4,249 estimates was received during the month from 51 observers, as follows:

Observer	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.
Adams	28	71	Knowles	15	19
Ahnert	51	337	de Kock	117	508
Ancarani	9	10	Lacchini	41	43
Armfield	3	10	Lankford	15	38
Ball	8	8	LeVaux	19	20
Bogard	56	134	Lowder	9	9
Cain	14	17	Mary	40	59
Chandra	87	96	Miller	41	41
Charles	21	28	Oravec	61	190
Cragg	31	31	Parker	23	23
Darnell	2	4	Pearcy	31	32
Diedrich, DeL.	1	4	Peltier	186	230
Diedrich, G.	3	8	Penhallow	37	64
Drakakis	17	56	Pierson	86	100
Escalante	126	158	Reeves	1	1
Estremadoyro, G. A.	4	4	Renner	58	58
Estremadoyro, V. A.	6	6	Rosebrugh	18	100
Fernald	323	612	Taboada	138	212
Ford	10	10	Tifft	4	4
Galbraith	16	156	Toche	8	13
Greenley	71	151	Venter	11	16
Halbach	37	37	Waters	5	5
Hartmann	167	183	Welker	30	50
Herring	53	56	Yamada	14	40
Hirose	24	152	—		—
Irland	17	25	51	totals	4,249
Kelly	10	10			

Nova Search: Reports on the Nova Search program were received from 3 observers on areas as follows:

Adams: 16, 17, 33, 34.

Rosebrugh: Dome, 1, 34.

Smith, F. W.: 3, 4.

January 15, 1950.

Comet Notes

By DANIEL L. HARRIS III

The recovery of PERIODIC COMET VÄISÄLÄ (1) was accomplished by Mrkos of the Skalnate Observatory on 19 December 1949 and the comet has received the designation 1949 *h*. It appeared as a diffuse object without central condensation of apparent magnitude 17. A comparison with the predicted ephemeris position indicates that it came to perihelion on 11 November 1949, about one day later than predicted.

The comet discovered by Wilson and Harrington (1949 *g*) has proved to be a very interesting object. According to Dr. Cunningham's preliminary orbit this comet has a period of only 2.3 years. This is still uncertain by two years or more, but, if supported by additional observations, would be the shortest known period for a comet. Encke's comet has a period of 3.30 years, and has been observed at many oppositions.

No other comets are visible with small telescopes at this time, although several faint comets are under observation with the larger instruments.

Warner and Swasey Observatory, East Cleveland, Ohio.

General Notes

Dr. Joel Stebbins, emeritus director of the Washburn Observatory, University of Wisconsin, and now research associate in the Lick Observatory, University of California, has been awarded the Gold Medal of the Royal Astronomical Society, London, England.

The Rittenhouse Astronomical Society, of Philadelphia, held its monthly meeting on January 13, 1950, in the Randal Morgan Physics Laboratory, University of Pennsylvania. The speaker, Dr. Raymond Wilson, Temple University, took as his topic, "Some Contributions of the Interferometer to Double Star Research."

New officers of the Rittenhouse Astronomical Society, recently elected, are: President, Dr. I. M. Levitt, Director of Fels Planetarium; Vice-President, Dr. Samuel G. Barton, Flower Observatory; Secretary, Mrs. R. M. Cole, Bryn Athyn Academy, Bryn Athyn, Pa.

Provisional Relative Sunspot Numbers for December, 1949*

1	190	11	137	21	92
2	168	12	143	22	110
3	155	13	150	23	103
4	125	14	105	24	119
5	108	15	107	25	140
6	97	16	106	26	129
7	124	17	96	27	107
8	120	18	100	28	114
9	122	19	115	29	101
10	124	20	88	30	90
				31	110

Mean for December 118.9.

*From the Zürich Observatory, furnished by Mr. Neal J. Heines.

The Cleveland Astronomical Society

The renowned Harvard astronomer, Dr. Cecelia Payne-Gaposchkin, addressed the group on January 20, 1950, on the topic "Stars that Vary in Brightness." Included in the lecture were the following points: a masterful summary of present knowledge in this field, a discussion of the stellar populations in the "hub" and "arms" of the galaxy (as opposed to populations I and II), and an indication as to the manner in which the different classes of variables are distributed throughout the galaxy. As the results of her work are to be published, the reader is referred to the Harvard publications for further details.

PAUL ANNEAR, *Recording Secretary.*
Burrell Observatory, Baldwin-Wallace College, Berea, Ohio.

The Ohio Neighborhood Astronomers

The fifty-seventh meeting of this group was held in Columbus at Ohio State University on January 21, 1950. In addition to the usual large Ohio group, representatives were present from Harvard and the Universities of Michigan, Indiana, and Pittsburgh. The scheduled program was devoted entirely to a review of the current work at the Perkins Observatory. The speakers and subjects follow:

Geoffrey Keller—Evolution of Spherical Galaxies.

Nelson Limber—Photoelectric Observations of Three Eclipsing Binaries.

P. C. Keenan—Remarks on Unidentified Bands in Late-type Spectra.

Arne Slettebak—A Program of Obtaining Blue and Infrared Spectrograms of the Brighter Be-Stars.

J. Allen Hynek—a. The McGraw-Hill Book on Astrophysics. b. A Spectroscopic Search for Cool Companions of B-Type Stars.

A supplementary report on the Siberian (Sikhote-Alin) meteorite of February 12, 1947, was presented by Bobrovnikoff. The new planetarium (Spitz projector) was demonstrated at the McMillin Observatory by Hynek. Dinner and informal discussion at the Faculty Club closed the meeting.

The Institute for the Unity of Science. The Institute for the Unity of Science, supported by the American Academy of Arts and Sciences and by the Rockefeller Foundation, is an educational corporation chartered in the State of New York. "The purposes for which the corporation is formed are to encourage the integration of knowledge by scientific methods, to conduct research in the psychological and sociological background of science, to support the International Movement for the Unity of Science. . . ."

This Institute is promoting a contest for which a prize of $300 will be awarded for the best essay submitted on the theme, "The Divorce Between Science and Philosophy, Its historical origins, its logical basis, and proposals for its termination." Two additional prizes of $100 each will be given for the next best two essays.

Science and philosophy were not distinguished sharply in antiquity. Subsequently, and especially since the 18th century, philosophy came to be regarded as a special branch of knowledge, separated by more or less explicitly formulated boundaries from the various special sciences. The consequences of this separation have been far-reaching, and participants in the Essay Contest are expected to clarify the issues involved in it. For details as to rules and dates, you are asked to write to Institute for the Unity of Science, American Academy of Arts and Sciences, 28 Newbury Street, Boston 16, Massachusetts.

Amateur Astronomy in Japan

It is a remarkable thing that astronomy has not been included until recently in the course of common education in Japan. Many students of high schools and junior high schools are now interested in astronomy, and most of them show much enthusiasm in observing the heavenly bodies with telescopes. A few schools have reflectors of 5 or 6-inches or refractors of 2 or 3-inches only.

There are two astronomical societies throughout the country; the Astronomical Society of Japan and the Oriental Astronomical Association. The former has published a semi-popular magazine "The Astronomical Herald" monthly, since its foundation in 1908, and began to publish a periodical for specialists written in English last summer (as was reported in your November issue). The latter, being founded in 1920, also publishes a popular magazine "The Heavens," monthly. Besides these societies there are many local ones belonging mostly to high schools and junior high schools.

It is regretful that we can find only few amateur astronomers duly trained for the astronomical observations (for sun-spots, meteors, variable stars, etc.), which were so common in Japan before the war. Among them the sudden death of Mr. K. Kozawa last spring is very lamentable. Mr. Kozawa was one of the skillful observers of variable stars (especially of SS Cygni-type stars).

Many professional astronomers are eager to popularize astronomy among the citizens and students. The names of Dr. I. Yamamoto of Tanakami Observatory, Dr. T. Araki at Kyoto-fu, and Mr. S. Kanda in Tokyo may be cited here. Mr. K. Komaki in Wakayama is active also for promoting the meteor observations many years since.

T. Murakami.

Hiroshima University, Japan.

Summary of Sunspot Observations at Mount Holyoke College, 1949

Month	No. of Obs.	North of Equator No. of Groups	North of Equator Av. Lat.	South of Equator No. of Groups	South of Equator Av. Lat.	Av. No. Groups at one Obs.	New Groups
January	16	15	+14°8	22	—10°8	7.9	33
February	20	22	14.6	23	11.2	10.2	40
March	23	25	12.1	24	10.4	9.9	44
April	20	22	12.6	21	12.6	9.8	36
May	27	24	13.9	15	11.3	7.3	35
June	26	22	14.7	19	9.9	6.6	35
July	26	19	14.0	21	16.5	7.7	33
August	26	13	11.5	17	13.1	6.2	26
September	24	23	13.8	21	14.9	9.1	36
October	24	28	14.9	21	14.2	7.8	46
November	20	27	14.8	16	10.1	8.3	40
December	23	24	+16.5	15	— 8.7	7.2	28
Totals	275	264		235			432

Average number of groups at one observation..... 8.08
Average latitude of 230 groups north of the equator.....+14°29
Average latitude of 202 groups south of the equator.....—11°85

In this report it would seem that the two indices of solar activity least likely to be seriously affected by variation in the number of days on which observations were made are (a) the average number of groups seen at one observation 8.1 (8.4 for 1948), and (b) the total number of new groups 432 (433 for 1948). These two indicate rather a plateau than a down grade in current activity.

In this connection, however, it may be noted that a total count of 14056 spots

on 275 days yields 51 as the average number of *spots* counted at a single observation, to be compared with 64 and 67 in 1948 and 1947, respectively. The spot-index shows a greater drop than the group-index.

The slightly greater spottedness of the sun's northern hemisphere, as compared with the southern, matches almost exactly the preponderance of southern over northern in the previous year. Average latitudes of northern and southern groups have decreased by 0°.5 and 1°.3, respectively. One group in May and two in November were recorded on the solar equator. Half a dozen groups occurred as much as 30° from the equator: two in July, two in October, all south; two in December, north, and all in differing longitudes. The 29 groups in latitude ±25° or beyond were evenly divided north and south. Activity was rather uniformly distributed in longitude, with 75, 71, 73, 72, 77, and 64 groups occurring in the six regions 0° to 60°, 61° to 120°, etc., respectively.

Observations were made largely by Mrs. Katherine Tinker, Miss J. Hornor, and Miss Farnsworth. Miss M. Vogt, Miss E. Reed, Miss R. Botley, Miss E. Jacoby, and Miss A. Harrison gave invaluable assistance at certain times in the college vacations.

ALICE H. FARNSWORTH.

John Payson Williston Observatory, Mount Holyoke College, South Hadley, Mass., January, 1950.

Book Reviews

Astronomisch-Geodätisches Jahrbuch für 1950. (Published by G. Braun, Karl-Friedrich-Strasse 14, Karlsruhe a. Rhein.)

On page 200 of the preceding volume, we mentioned the appearance of the volume for 1949 bearing the given title. Now we are in receipt of the current volume. The description given for its predecessor is applicable to this new volume also. It contains a few more pages than formerly, but the general format and content are the same. It will be useful during the year for many problems related to positional astronomy. It is also an encouraging indication of the recovery science is achieving in Germany. C.H.G.

Zur Photometrie der Doppelsterne, by Hans Kienle. (Akademie-Verlag, Berlin.) The above title pertains to a small-sized pamphlet of twenty pages. The author states that an understanding of the components of close pairs of double stars is important to a comprehension of the stellar system as a whole. He states also that the determination of the relative brightness of the components is beset with greater difficulty as the separation of the pairs becomes smaller and the difference in intensity becomes larger. He mentions three devices he has used to overcome the difficulty: (a) Optic separation by means of a prism in the focal plane of a long-focus instrument; (b) Production of artificial companions by means of screens; (c) Production of spectra with spectrographs of small dispersion, using greatest possible range of wave lengths.

He used the first with success, but was interrupted in investigating the others through the vicissitudes of war. He is now resuming his work with new equipment. C.H.G.